IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: James Edward Martin *et al.*	§	Group Art Unit: 3662
	§	
Serial Number: 10/530,695	§	Examiner: Unknown
	§	
Confirmation Number: 7716	§	Atty Dkt No.: 14.0223-PCT-US
	§	
Filing Date: October 13, 2003	§	
	§	
Entitled: METHOD AND APPARATUS FOR POSITIONING OF SEISMIC SENSING CABLES	§ § §	

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Index of documents

accompanied a request for participation in the Patent Prosecution Highway (PPH) Pilot Program between the UKIPO and the USPTO.

1. The request (2 pages)
2. **This index (1 page)**
3. Preliminary amendment (9 pages)
4. Search report from UK IPO, 10 February, 2003 (12 pages, including a cover)
5. Examination report from UK IPO, 8 June, 2005 (20 pages, including a cover)
6. Further examination report from UK IPO, 28 December, 2005 (4 pages, including a cover)
7. Further examination report from UK IPO, 30 March, 2006 (3 pages, including a cover)
8. Notification of Grant, 27 June, 2006 (3 pages, including a cover)
9. UK patent, GB 2 394 045 B, 26 July, 2006 (30 pages, including a cover)
10. Non-US references cited by GB search report, GB2089043A (Chevron Research), WO 84/03153 A (Kongsberg), FR 002772931 A (CIE GENERALE), and FR 002772134 A (AQASS). These references were disclosed in an IDS filed on 1/11/2007, among other references. (54 pages, including covers).
11. Two IDS were submitted in this case, a first one on 4/8/2005 together with the national phase entrance; a second one on 1/11/2007. (copy not included)

PTO/SB/20 (09-07)
Approved for use through 12/31/2008 OMB 0651-0058
U.S. Patent and Trademark Office; U.S DEPARTMENT OF COMMERCE

REQUEST FOR PARTICIPATION IN THE PATENT PROSECUTION HIGHWAY (PPH) PILOT PROGRAM BETWEEN THE (1) JPO OR (2) UKIPO, AND THE USPTO

Application No.:	10/530,695	First Named Inventor:	James Edward Martin
Filing Date:	October 13, 2003	Attorney Docket No.:	14 0223-PCT-US
Title of the Invention:	METHOD OF AND APPARATUS FOR POSITIONING OF SEISMIC SENSING CABLES		

THIS REQUEST FOR PARTICIPATION IN THE PPH PILOT PROGRAM MUST BE FAXED TO:
THE OFFICE OF THE COMMISSIONER FOR PATENTS AT 571-273-0125 DIRECTED TO THE ATTENTION OF MAGDALEN GREENLIEF

APPLICANT HEREBY REQUESTS PARTICIPATION IN THE PATENT PROSECUTION HIGHWAY (PPH) PILOT PROGRAM AND PETITIONS TO MAKE THE ABOVE-IDENTIFIED APPLICATION SPECIAL UNDER THE PPH PILOT PROGRAM.

The above-identified application validly claims priority under 35 U.S.C. 119(a) and 37 CFR 1.55 to one or more corresponding JPO application(s) or UKIPO application(s).

The ☐ JPO ☒ UKIPO application number(s) is/are: 0223673.5

The filing date of the ☐ JPO ☒ UKIPO application(s) is/are: 11 October, 2002

I. List of Required Documents;

a. **A copy of all JPO office actions (excluding "Decision to Grant a Patent"*) in the above-identified JPO application(s), or a copy of all UKIPO office actions in the above-identified UKIPO application(s).**

☒ Is attached.

☐ Is available via Dossier Access System. Applicant hereby requests that the USPTO obtain these documents via the Dossier Access System.

*It is not necessary to submit a copy of the "Decision to Grant a Patent" and an English translation thereof.

b. **A copy of all claims which were determined to be patentable by the JPO in the above-identified JPO application(s), or a copy of all claims which were determined to be patentable by the UKIPO in the above-identified UKIPO application(s).**

☒ Is attached.

☐ Is available via Dossier Access System. Applicant hereby requests that the USPTO obtain these documents via the Dossier Access System.

c. **English translations (where applicable) of the documents in a. and b. above along with a statement that the English translations are accurate are attached.**

Information disclosure statement listing the documents cited in the JPO office actions or UKIPO office actions is attached.

Copies of all documents are attached except for U.S. patents or U.S. patent application publications

REQUEST FOR PARTICIPATION IN THE PATENT PROSECUTION HIGHWAY (PPH) PILOT PROGRAM BETWEEN THE (1) JPO OR (2) UKIPO, AND THE USPTO

(continued)

Application No.:	10/530,695	First Named Inventor:	James Edward Martin

II. Claims Correspondence Table:

Claims in US Application	Patentable Claims in JP/UKIPO Application	Explanation regarding the correspondence
44-62	1-19	Substantially identical.
63-64	20-21	Substantially identical.
none	22-24	The claims in GB patent were not presented.
65-70	25-30	Substantially identical.
71-73	31-33	Substantially identical.
74	none	US claim is not presented.
none	34-35	The claims in GB patent were not presented.
75-76	36-37	Substantially identical.
77	none	US claim is not presented (canceled).
78-82	38-42	Substantially identical.

III. All the claims in the US application sufficiently correspond to the patentable/allowable claims in the JPO or UKIPO application.

IV. Payment of Fees:

The Commissioner is hereby authorized to charge the petition fee under 37 CFR 1.17(h) as required by 37 CFR 1.102(d) to ☒ Deposit Account No. 50-1720.

☐ Credit Card. Credit Card Payment Form (PTO-2038) is attached.

Signature	[signature]	Date	11/28/2007
Name (Print/Typed)	Liangang (Mark) Ye	Registration Number	48,276

Remote User

lgoldsmith

14.0223-GB, 20060726, GB2394045B.pdf
11/20/07 04:07 PM

26 July, 2006

30 pages

(12) UK Patent (19) GB (11) 2 394 045 (13) B

(45) Date of publication: 28.07.2006

(54) Title of the invention: Method and apparatus for positioning of seismic sensing cables

(51) INT CL: G01V 1/38 (2006.01)

(21) Application No: 0223673.5

(22) Date of Filing: 11.10.2002

(43) Date A Publication: 14.04.2004

(52) UK CL (Edition X):
G1G GMC GRA

(56) Documents Cited:
GB 2089043 A
FR 002772931 A
US 4845658 A
US 4635236 A
US 4376301 A
WO 1984/003153 A
FR 002772134 A
US 4641287 A
US 4555779 A

(58) Field of Search:
As for published application 2394045 A *viz:*
UK CL (Edition T) G1G
INT CL^7 G01S, G01V
Other: Online WPI, EPODOC, JAPIO
updated as appropriate

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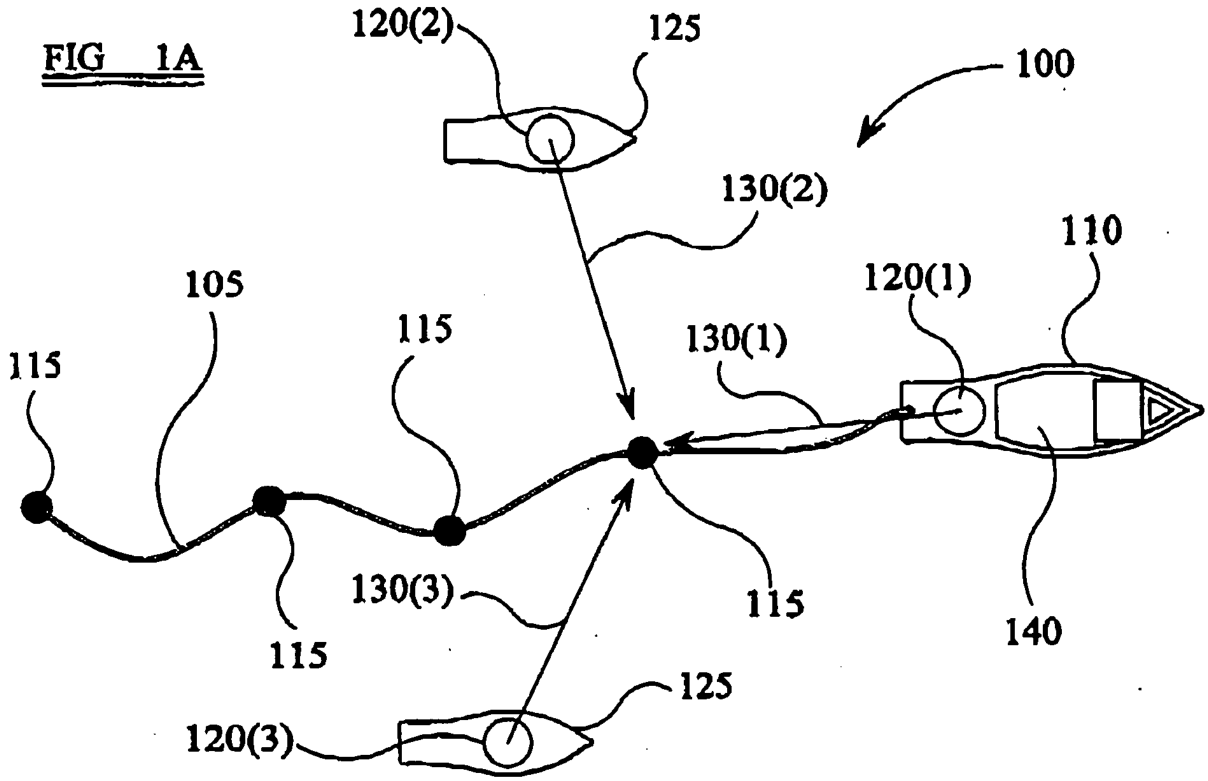
FIG 1A


120(2)
125
100
130(2)
110
120(1)
105
115
130(1)
115
115
130(3)
115
115
140
125
120(3)

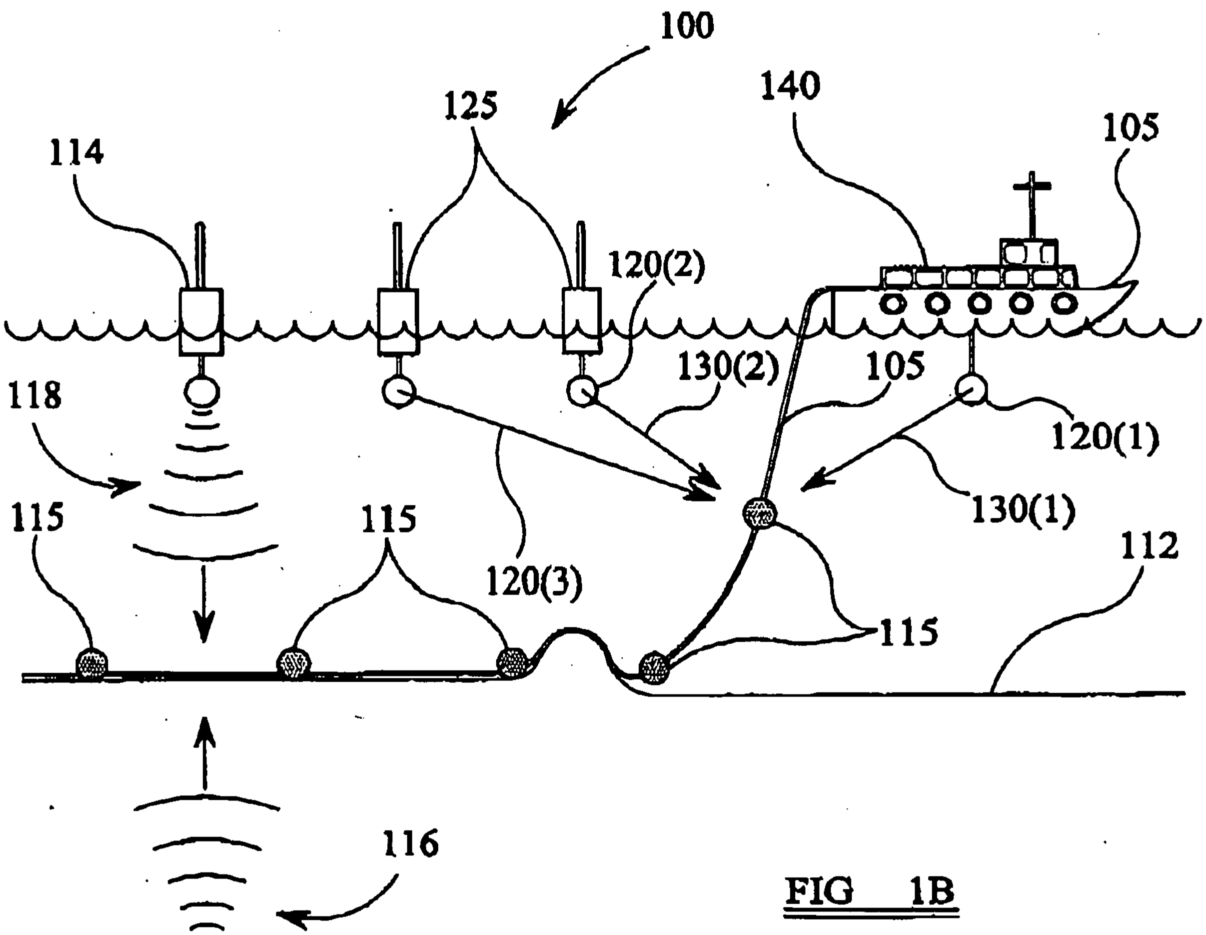

100
125
140
105
114
120(2)
118
130(2)
105
120(1)
130(1)
115
115
120(3)
112
115
116

FIG 1B

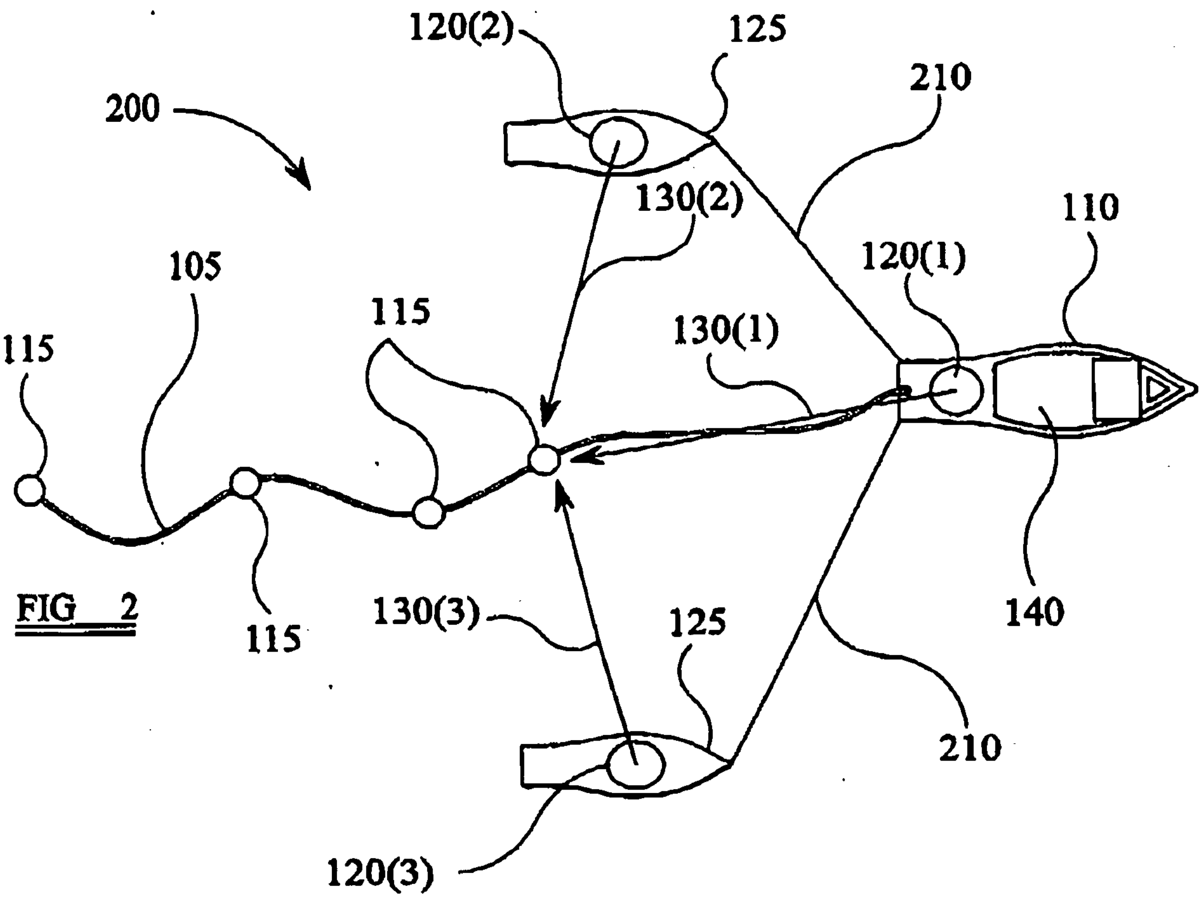

120(2)
125
210
200
130(2)
110
105
120(1)
115
115
130(1)
140
115
130(3)
125
210
120(3)

FIG 2

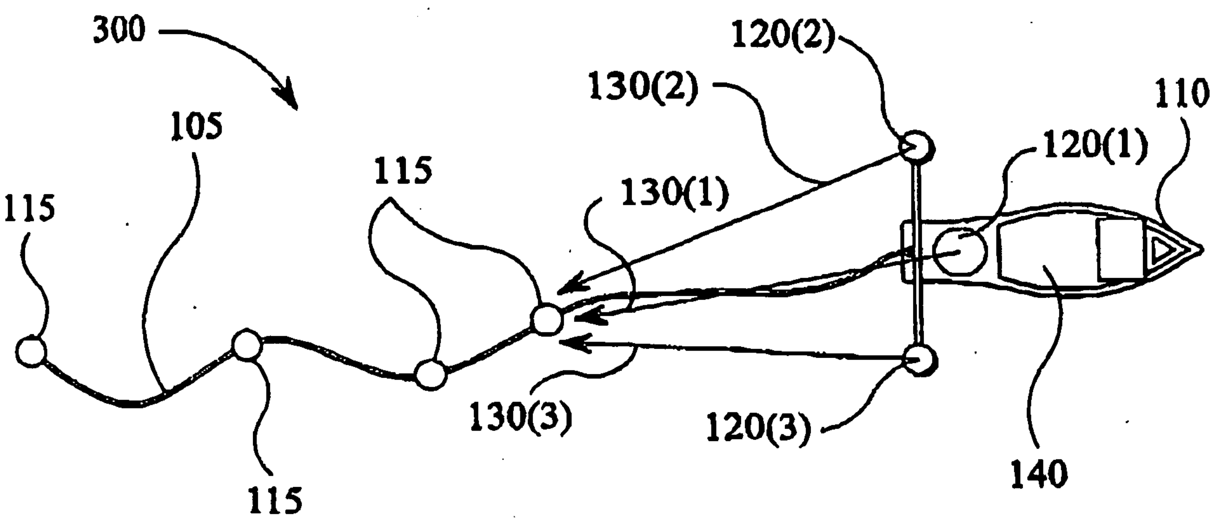
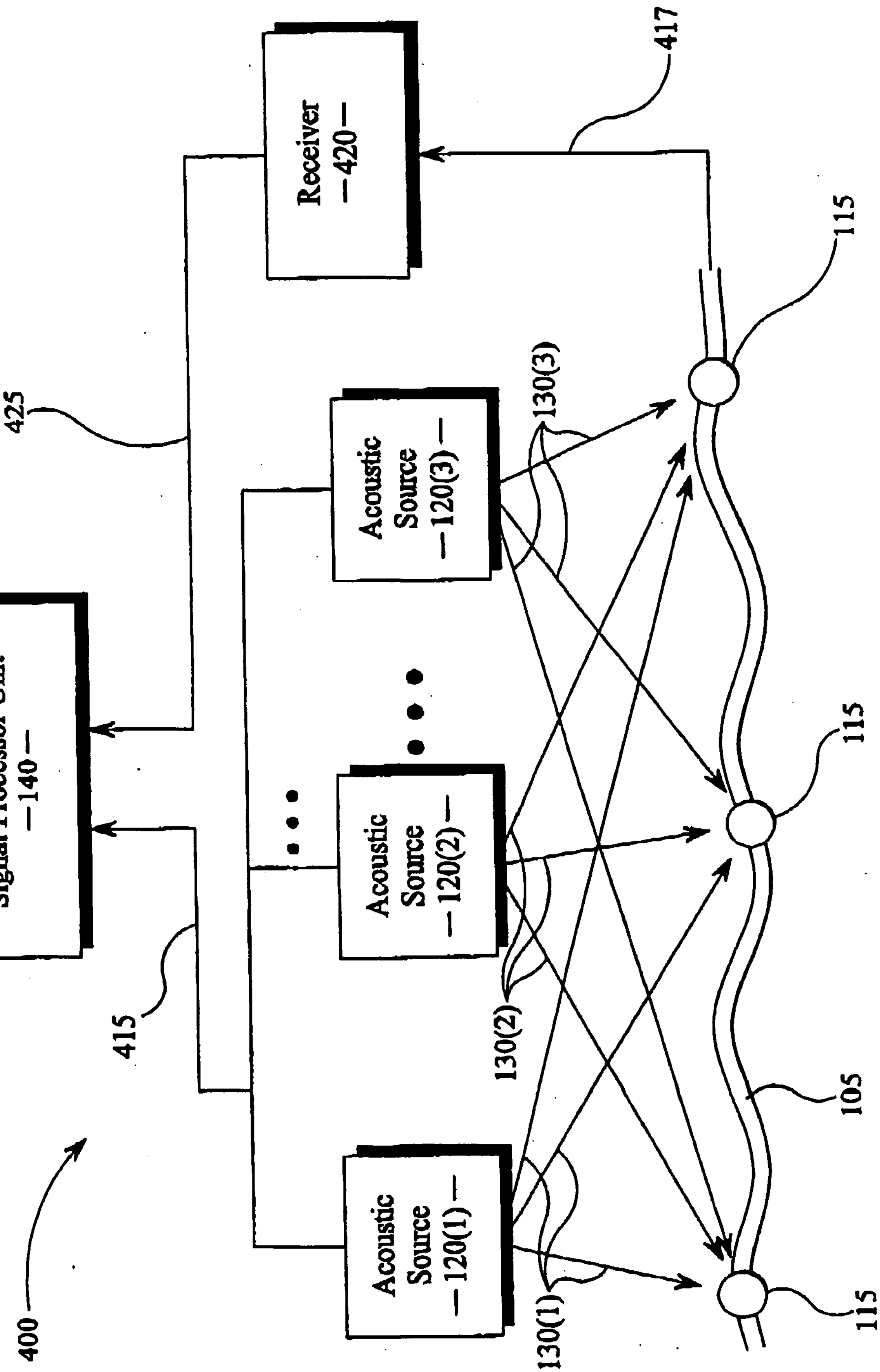

300
120(2)
130(2)
110
105
120(1)
115
130(1)
115
130(3)
120(3)
140
115

FIG 3



400
Signal Processor Unit —140—
Receiver —420—
417
425
415
Acoustic Source —120(1)—
Acoustic Source —120(2)—
Acoustic Source —120(3)—
130(1)
130(2)
130(3)
115
115
115
105

FIG 4

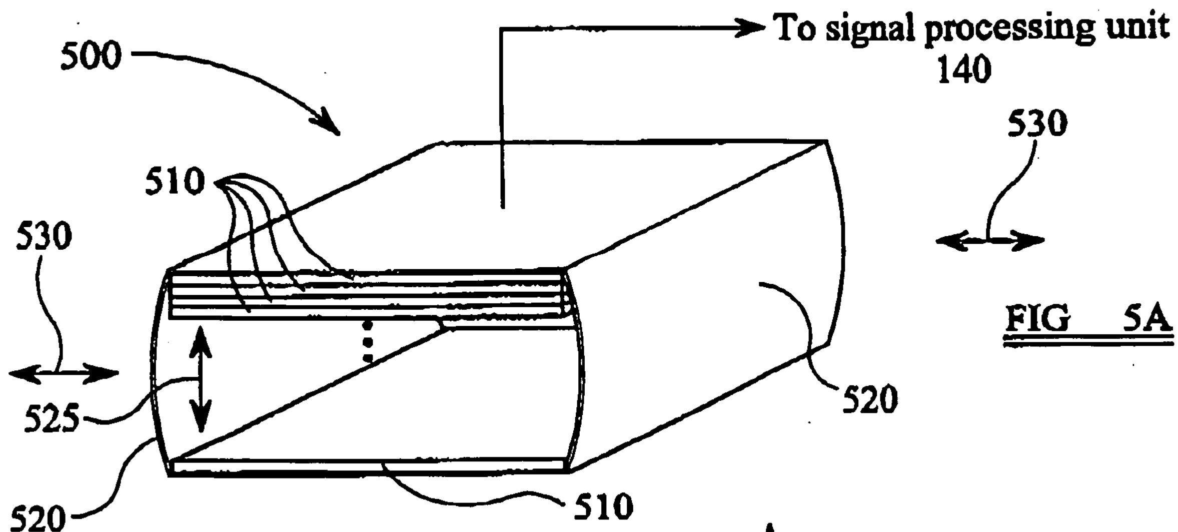


FIG 5A

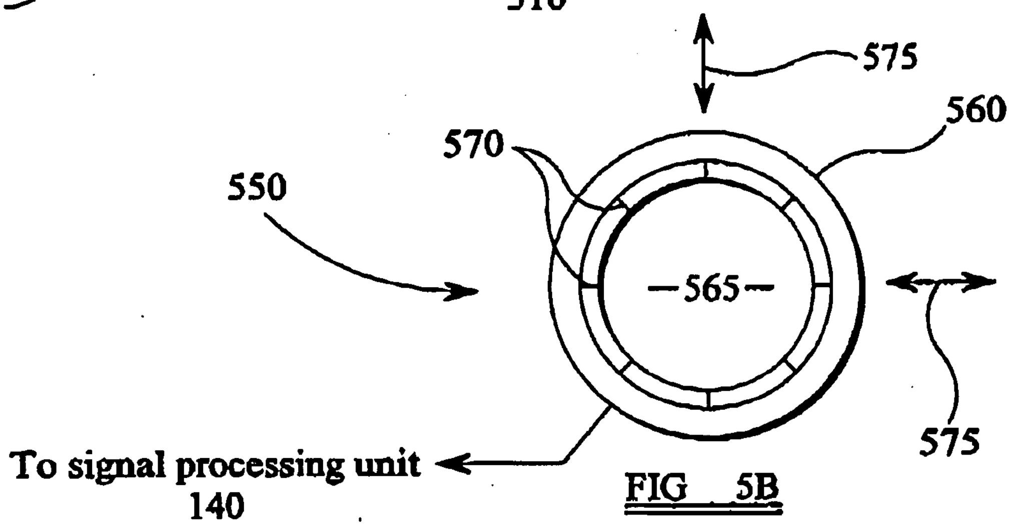


FIG 5B

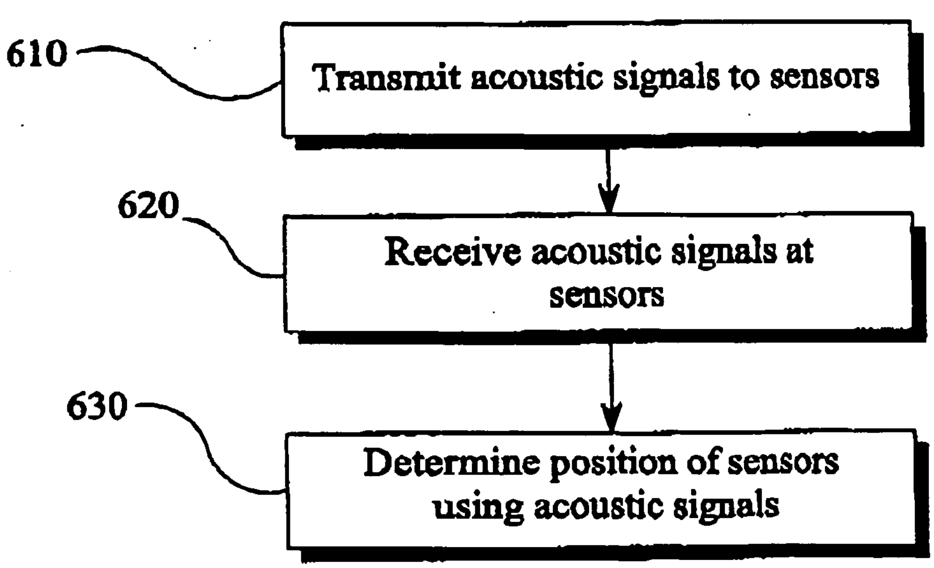


FIG 6

METHOD AND APPARATUS FOR POSITIONING OF SEISMIC SENSING CABLES

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to marine seismic surveying, and is more particularly concerned with a method and apparatus for determining the position of a seismic cable being used to perform a marine seismic survey.

2. DESCRIPTION OF THE RELATED ART

Seismic exploration is widely used to locate and/or survey subterranean geological formations for hydrocarbon deposits. As many commercially valuable hydrocarbon deposits are located beneath bodies of water, various types of marine seismic surveys have been developed. In a typical marine seismic survey, an array of marine seismic streamer cables is towed at about 2.57 m/s (5 knots) behind a seismic survey vessel. The seismic streamer cables may be several thousand meters long and contain a large number of sensors, such as hydrophones and associated electronic equipment, which are distributed along the length of the each seismic streamer. The survey vessel also tows one or more seismic sources, such as airguns and the like.

Acoustic signals, or "shots," produced by the seismic sources are directed down through the water into the earth beneath, where they are reflected from the various earth strata. The reflected signals are received by the hydrophones in the seismic streamer cables, digitized and then transmitted to the seismic survey vessel, where they are recorded and at least partially processed with the ultimate aim of building up a representation of the earth

strata in the area being surveyed. Analysis of the representation may indicate probable locations of geological formations and hydrocarbon deposits.

The accuracy of the seismic analysis is generally limited by uncertainties in the estimated and/or measured positions of the seismic sensors. The positions of deployed seismic sensors may be estimated using modeling techniques that predict the position of the deployed seismic sources. For example, the position of a seismic cable on the sea floor may be estimated using models that consider the physical characteristics of the seismic cable (*e.g.*, weight, diameter, *etc.*) and the effect of predicted sea currents on the seismic cable as it descends to the sea floor. However, such methods are predicated on a limited knowledge of the properties of water in the catenary, as well as the geology of the sea floor, and thus they only provide an estimate of the seismic cable's location.

A variety of measurement techniques have been developed to determine the position of the seismic sources and the seismic sensors as the seismic sensors descend through the catenary and come to rest on the sea floor. For example, the seismic source is fired and the arrival time of the shot at the sensors is then used to determine the position of the seismic cable by triangulation. This technique cannot generally be used during a survey, however, because the shots used to determine the position of the seismic sensors often interferes with the shots used to generate the seismic survey data. Alternatively, acoustic signals produced by a seismic source survey array may be used to determine the seismic cable position. However, in addition to producing shots that interfere with the seismic survey data, the large area of the seismic source array used in this technique generally reduces the accuracy of the seismic cable position determination.

The position of seismic cables may also be measured by attaching ultra-short baseline (USBL) acoustic sensors to the seismic cable. The USBL acoustic sensors are suspended above the seismic cable using flotation collars. Although the USBL acoustic sensors can provide reasonably accurate ranges and bearings from the seismic survey vessel, there remain a number of drawbacks to the use of USBL acoustic sensors. The USBL acoustic sensors are generally very expensive and are attached to the outside of the seismic cable, where they may interfere with seismic cable deployment. In addition, USBL acoustic sensors are typically depth-limited and they require an external source of power and/or a battery.

SUMMARY OF THE INVENTION

In one aspect of the instant invention, an apparatus is provided for determining the position of a seismic cable being used to perform a marine seismic survey. The apparatus includes at least one seismic sensor deployed on an ocean bottom cable and a plurality of sources deployed in a manner that is structurally independent of the seismic sensors and adapted to provide a positioning signal distinguishable from a seismic survey signal to the seismic sensors concurrently with the seismic survey signal.

In another aspect of the present invention, a method is provided for determining the position of at least one seismic sensor disposed on an ocean bottom cable and being used to perform a marine seismic survey. The method includes transmitting a plurality of positioning signals from a plurality of sources deployed in a manner that is structurally independent of the seismic sensor(s), the positioning signals being distinguishable from the seismic survey signal. The method further includes receiving the positioning signals at the seismic sensor(s)

concurrently with the seismic survey signal and determining the position of the seismic sensors from the received positioning signals.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

Figures 1A-B show different views of a first exemplary system for positioning of a seismic cable, in accordance with a first embodiment of the present invention;

Figure 2 shows a second exemplary system for positioning of the seismic cable, in accordance with a second embodiment of the present invention;

Figure 3 shows a third exemplary system for positioning of the seismic cable, in accordance with a third embodiment of the present invention;

Figure 4 shows a system for transmitting signals that are used to determine a position of the seismic cable shown in Figures 1A-B, 2, and 3;

Figures 5A-B show first and second exemplary piezoelectric acoustic sources that may be used in the system shown in Figure 4; and

Figure 6 shows a flow chart illustrating a technique for determining the locations of the sensors.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

Referring now to Figure 1A, a top view of a first exemplary system 100 for acoustic positioning of a seismic cable 105 is shown. The first exemplary system 100 includes a seismic survey vessel 110, which deploys the seismic cable 105 at a surface of a body of water, which, in alternative embodiments, may be freshwater, sea water, or brackish water. A

plurality of seismic sensors 115 are coupled to the seismic cables 105. The seismic cable 105 may descend through the catenary until it reaches the sea floor 112, as illustrated in Figure 1B. Although only one seismic cable 105 is shown in Figures 1A-B, the present invention is not so limited. In alternative embodiments, more seismic cables 105 may be deployed without departing from the scope of the present invention. In particular, an array of seismic cables 105 may be deployed.

In one embodiment of the first exemplary system 100, illustrated in Figure 1B, a seismic source 114 is deployed near the survey vessel 110. The seismic source 114 is generally towed behind the survey vessel 110 and may be part of an array of other seismic sources (not shown). However, it will be appreciated that, in alternative embodiments, the seismic source 114 may be deployed at any desirable location, including an array towed by a nearby vessel (not shown), suspended beneath the survey vessel 110, on a buoy (not shown), at the sea floor 112, and the like.

The seismic source 114 provides a seismic survey signal 118. In one embodiment, the seismic survey signal 118 is a broadband acoustic signal with a range of frequencies from 0 to about 120 Hz. The seismic survey signal 118 propagates into the earth and forms a reflected signal 116 when the seismic survey signal 118 reflects from geologic formations, such as hydrocarbon deposits As shown in Figure 1B, in one embodiment, the seismic sensors 115 receive the reflected signals 116. As discussed above, analysis of the reflected signals 116 received by the seismic sensors 115 is used to form a representation of the earth strata proximate to the seismic sensors 115 and thus to locate and/or survey geologic formations.

The accuracy of the analysis of the reflected signals 116 depends upon an accurate knowledge of the position of the seismic cable 105. The position of the seismic cable 105 is, however, difficult to determine. During and after deployment of the seismic cables 105, the size and shape of the seismic cable 105, currents in the body of water, the velocity of the survey vessel 110, and other like factors may cause the seismic cable 105 to move unpredictably through the water. Thus, in accordance with one embodiment of the present invention, a plurality of sources 120(1-3) transmit a plurality of positioning signals 130(1-3) to the seismic sensors 115, which receive the positioning signals 130(1-3).

In one embodiment, a first source 120(1) is suspended beneath the survey vessel 110. In alternative embodiments, the first source 120(1) may be mounted in a hull of the survey vessel 110 or in a through-hull chamber of the survey vessel 110. A second and a third source 120(2-3) are suspended beneath buoys 125. In various embodiments, the buoys 125 may be stationary or they may be autonomous, remote-controlled self-powered buoys 125 that follow the survey vessel 110. In one embodiment, the autonomous, remote-controlled self-powered buoys 125 follow the survey vessel 110 and maintain a fixed configuration. In one embodiment, the buoys 125 may be deployed along a length or the seismic cable 105 or amongst an array of seismic cables 105. Note that at least two of the seismic sources 120(1-3) are deployed in a manner structurally independent of the cable 105, *i.e.*, there is no structural relationship between the source 114 and the seismic cable 105.

Although three sources 120(1-3) and two buoys 125 are depicted in Figure 1A, the present invention is not so limited. Two or more sources 120(1-3) and any desirable number of buoys 125 may be deployed without departing from the scope of the present invention. For example, two sources 120(1-3) may be deployed in a linear grouping. For another example, four sources 120(1-3) may be deployed in an approximately rectangular grouping. For yet another example, five sources 120(1-3) may be deployed in an approximately pentagonal grouping. Furthermore, in alternative embodiments, additional sources 120(1-3) may also be positioned on, or controlled by, a second survey vessel (not shown).

As described in detail below and in accordance with one aspect of the present invention, the positioning signals 130(1-3) may be formed such that a signal processing unit 140 can distinguish between the positioning signals 130(1-3) and seismic survey signal 118. For example, in one embodiment, the positioning signals 130(1-3) have frequencies ranging from 700 HZ to 4500 Hz when the seismic survey signal 118 has a frequency range of 0 to 120 Hz. However, it will be appreciated by those of ordinary skill in the art having benefit of the present disclosure that the positioning signals 130(1-3) and seismic survey signal 118 do not have to be distinguished by frequency. For example, in alternative embodiments, the positioning signals 130(1-3) and seismic survey signal 118 may be distinguished by being modulated by orthogonal sequences, such as a Maximal sequence or a Kasami sequence.

The signal processing unit 140 determines the position of the seismic sensors 115 using the positioning signals 130(1-3) that are transmitted by the sources 120(1-3) and received by the seismic sensors 115. Although the signal processing unit 140 depicted in

Figures 1A-B is located on the survey vessel 110, the present invention is not so limited. In alternative embodiments, portions of the signal processing unit 140 may be positioned in the seismic sensors 115, the buoys 125, or at any other desirable location without departing from the scope of the present invention. It will further be appreciated by those of ordinary skill in the art having benefit of the present disclosure that the accuracy of the position determination depends on the number and type of sources 120(1-3) and seismic sensors 115. Thus, the phrase "determining the position" of the seismic sensors 115 and/or the seismic cable 105, will hereinafter be understood to mean determining the position of the seismic sensors 115 and/or the seismic cable 105 within a reasonable range of positions.

Referring now to Figure 2, a second exemplary system 200 for positioning of the seismic cable 105 is shown. In one embodiment of the second exemplary system 200, the sources 120(2-3) are suspended beneath buoys 125, which are coupled to the survey vessel 110 by cables 210. However, the present invention is not so limited. In one alternative embodiment of the second exemplary system 200, the sources 120(2-3) are mounted in the hulls of the buoys 125. In another alternative embodiment of the second exemplary system 200, the sources 120(2-3) are suspended beneath, or mounted on, depth-controlled cables 210 that are towed behind the survey vessel 110.

In addition to providing a mechanical connection between the buoys 125 and the survey vessel 110, the cables 210 may also provide a communication link between the buoys 125 and the survey vessel 110. For example, the cables 210 may include one or more electrically conductive wires or cables (not shown) that may transmit signals from the buoys 125 to the survey vessel 110. For another example, the cables 210 may include one or more

optical fibers (not shown) that may transmit signals from the buoys 125 to the survey vessel 110. However, in alternative embodiments, the cables 210 may not provide a communication connection between the buoys 125 and the survey vessel 110. For example, the buoys 125 may communicate with the survey vessel 110 via a wireless radio-frequency transmission.

Referring now to Figure 3, a third exemplary system 300 for acoustic positioning of a seismic cable 105 is shown. In the third exemplary system 300, the sources 120(2-3) are coupled to the survey vessel 110 by a boom 310. In one embodiment, the sources 120(2-3) are suspended from the boom 310 such that the sources 120(2-3) are at least partially submerged in the body of water. The boom 310 may also provide a communication connection between the sources 120(2-3) and the survey vessel 110. For example, the boom 310 may include one or more electrically conductive wires (not shown) that may transmit signals from the sources 120(2-3) to the survey vessel 110. For another example, the boom 310 may include one or more optical fibers (not shown) that may transmit signals from the sources 120(2-3) to the survey vessel 110. However, in alternative embodiments, the boom 310 may not provide a communication connection between the sources 120(2-3) and the survey vessel 110. For example, the sources 120(2-3) may communicate with the survey vessel 110 via a wireless radio-frequency transmission. It will also be appreciated that, in various alternative embodiments, more than one boom 310 may be coupled to the survey vessel 110.

Figure 4 shows a system 400 for transmitting the positioning signals 130(1-3), in accordance with one embodiment of the present invention. The sources 120(1-3) transmit the plurality of positioning signals 130(1-3), in accordance with one embodiment of the present

invention. For example, the sources 120(1-3) may transmit an up-sweep that ranges in frequency from 700 HZ to 2000 Hz. For yet another example, the sources 120(1-3) transmit an up-sweep that ranges in frequency from 1500 HZ to 4500 Hz. However, it will be appreciated by those of ordinary skill in the art having benefit of the present disclosure that the present invention is not so limited. In alternative embodiments, up-sweeps, down-sweeps, and any other desirable pattern having higher and/or lower frequency ranges may be used without departing from the scope of the present invention.

In one alternative embodiment, the sources 120(1-3) may also transmit orthogonal positioning signals 130(1-3). For example, the positioning signals 130(1-3) may be modulated by an orthogonal sequence, such as a Maximal sequence, a Kasami sequence, and the like. In another alternative embodiment, the sources 120(1-3) may be frequency multiplexed.

The sources 120(1-3) also transmit a signal 415 indicative of the positioning signals 130(1-3) to the signal processing unit 140, which may use the signal 415 to determine the position of the seismic sources 115, as described in detail below. The signal processing unit 140 in the system 400 may communicate with the sources 120(1-3) in any of a variety of manners well know to those of ordinary skill in the art having benefit of the present disclosure including, but not limited to, conductive wires, optical fibers, wireless electromagnetic transmissions, and the like. Although the signal processing unit 140 is depicted as a single unit in Figure 4, the present invention is not so limited. In alternative embodiments, portions (not shown) of the signal processing unit 140 may be positioned on

the buoys 125, the survey vessel 110, or any other desirable location without departing from the scope of the present invention.

Figure 5A shows a first exemplary piezoelectric acoustic source 500 that may be used as at least one of the sources 120(1-3). In one embodiment, the first exemplary piezoelectric acoustic source 500 is formed from a plurality of piezoelectric wafers 510 that are coupled to at least one flexible membrane 520. To transmit the positioning signals 130(1-3), the piezoelectric wafers 510 expand and/or contract along the direction indicated by the arrows 525. The flexible membrane 520 moves in response to the expansion and/or contraction of the piezoelectric wafers 510 along the directions indicated by the arrows 530. The motion of the flexible membrane 520 generates the positioning signals 130(1-3).

Figure 5B shows a second exemplary piezoelectric acoustic source 550 that may be used as at least one of the sources 120(1-3). In one embodiment, the second exemplary piezoelectric acoustic source 550 is formed from a piezoelectric ring 560 that is coupled to an interior flexible membrane 565 by a plurality of connectors 570. Although the piezoelectric ring 560 and the interior flexible membrane 565 have been depicted as circular, the present invention is not so limited. In alternative embodiments, the piezoelectric ring 560 and the interior flexible membrane 565 may be oval, rectangular, triangular, or any other desirable shape without departing from the scope of the present invention.

To transmit the positioning signals 130(1-3), the piezoelectric ring 560 expands and/or contracts along the direction indicated by the arrows 575. The interior flexible membrane 565 moves along the directions indicated by the arrows 575 in response to the

expansion and/or contraction of the piezoelectric ring 560 and generates the positioning signals 130(1-3).

Referring back to Figure 4, in one embodiment, the positioning signals 130(1-3) are received by the sensors 115, which communicate a sensed signal 417 to a receiver 420. For example, the sensors 115 may communicate the sensed signal 417 to the receiver 420 via a data telemetry unit (not shown) included in the sensors 115 and conductive wires (not shown) in the cable 105. However, in alternative embodiments, the sensed signal 417 may be communicated to the receiver 420 in any desirable manner including, but not limited to, wireless transmissions, optical devices, and the like.

The received signal 417 will generally include contributions from the positioning signals 130(1-3) and the seismic survey signal 118. When determining the position of the seismic cable 105, it may be desirable to distinguish the contributions from the positioning signals 130(1-3) from the seismic survey signal 118. Thus, the positioning signals 130(1-3) are distinguishable from the seismic survey signal 118. For example, the seismic survey signal 118 typically ranges in frequency from 0 Hz to 120 Hz. In one embodiment, the positioning signals 130(1-3) have frequencies in the range 700 Hz to 4500 Hz, and are therefore distinguished from the seismic survey signal 118 by frequency. In alternative embodiments, it will be appreciated that portions of this process may be carried out in the sensors 115, the receiver 420, the signal processing unit 140, a combination of the above, or at any other desirable location without departing from the scope of the present invention.

The receiver 420 provides a received signal 425 to the signal processing unit 140. The received signal 425 includes at least the portion of the sensed signal 417 that is contributed by the positioning signals 130(1-3). The receiver 420 may, in one embodiment, record the received signal 425 on tape and then provide the tape to the signal processing unit 140. However, the present invention is not so limited. In alternative embodiments, the receiver 420 may provide the received signal 425 using conductive wires, optical fibers, radio-frequency transmissions, computer disks, and the like.

The signal processing unit 140 determines the locations of the sensors 115 using the received signal 425 and the signal 415. In one embodiment, the signal processing unit 140 may use conventional cross-correlation techniques to determine the distance from the sources 120(1-3) to the sensors 115 using the received signal 425 and the signal 415. The signal processing unit 140 may then triangulate to determine the location of the sensors 115. It will, however, be appreciated that, in alternative embodiments, additional information may be included in the received signal 425 and used to determine the location of the sensors 115. For example, the sensors 115 may determine the bearing of the positioning signals 130(1-3) and the signal processing unit 140 may use the bearing to determine the location of the sensors 115. The bearing of the positioning signals 130(1-3) may also be used to determine the heading of each sensor 115.

Figure 6 shows a flow chart illustrating a technique for determining the locations of the sensors 115, in accordance with one embodiment of the present invention. One or more positioning signals 130(1-3) are transmitted (at 610) from the sources 120(1-3), which are structurally independent of the sensors 115, to the sensors 115, in the manner described in

detail above. In one embodiment, a piezoelectric acoustic source 500, 600 transmits (at 610) the positioning signals 130(1-3) to sub-sea sensors 115 in a marine environment. In another embodiment, an airgun transmits (at 610) the positioning signals 130(1-3) to sub-sea sensors 115 in a marine environment. The positioning signals 130(1-3) are received (at 620) by one or more sensors 115 and, as described above, the position of the sensors 115 is determined (at 630). For example, in one embodiment, the position of the sensors is determined (at 630) by determining (at 630) the distances from the sources 120(1-3) to the sensors 115 and then triangulating.

This concludes the detailed description. The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

CLAIMS

1. An apparatus, comprising:

at least one seismic sensor deployed on an ocean bottom cable; and

a plurality of sources deployed in a manner structurally independent of the or each seismic sensor and adapted to provide, to the or each seismic sensor, a positioning signal, distinguishable from a seismic survey signal, concurrently with the seismic survey signal.

2. An apparatus as claimed in claim 1, wherein the sources are adapted to provide the positioning signal at a frequency outside the frequency range of the seismic survey signal.

3. An apparatus as claimed in claim 2, wherein the sources are adapted to provide the positioning signal at a frequency above the frequency range of the seismic survey signal.

4. An apparatus as claimed in claim 3, wherein the sources are adapted to provide the positioning signal having a frequency range.

5. An apparatus as claimed in claim 4, wherein the frequency range is approximately 700 Hz to 2000 Hz.

6. An apparatus as claimed in claim 4, wherein the frequency range is approximately 1500 Hz to 4500 Hz.

7. An apparatus as claimed in claim 1, wherein the plurality of sources comprises between two and five sources, inclusive.

8. An apparatus as claimed in claim 7, wherein the plurality of sources comprises three sources.

9. An apparatus as claimed in claim 1, wherein the plurality of sources are piezoelectric sources.

10. An apparatus as claimed in claim 1, further comprising a signal processing unit adapted to determine the position of the or each seismic sensor from the received positioning signal.

11. An apparatus as claimed in claim 10, wherein the signal processing unit is adapted to determine the position of the or each seismic sensor using a plurality of propagation times from the plurality of sources to the at least one seismic sensor.

12. An apparatus as claimed in claim 11, wherein the signal processing unit is adapted to determine the position of the or each seismic sensor by triangulation using the plurality of propagation times from the plurality of sources to the at least one seismic sensor.

13. An apparatus, comprising:

at least one seismic sensor deployed on a sea bed; and

a plurality of sources adapted to provide to the or each seismic sensor a positioning signal, distinguishable from a seismic survey signal, concurrently with the seismic survey signal.

14. An apparatus as claimed in claim 13, wherein the sources are adapted to provide the positioning signal at a frequency outside the frequency range of the seismic survey signal.

15. An apparatus as claimed in claim 14, wherein the sources are adapted to provide the positioning signal at a frequency above the frequency range of the seismic survey signal.

16. An apparatus as claimed in claim 15, wherein the sources are adapted to provide the positioning signal having a frequency range.

17. An apparatus as claimed in claim 16, wherein the frequency range is approximately 700 Hz to 2000 Hz.

18. An apparatus as claimed in claim 16, wherein the frequency range is approximately 1500 Hz to 4500 Hz.

19. A method of determining a position of at least one seismic sensor deployed on an ocean bottom cable and capable of receiving a seismic survey signal, the method comprising:

transmitting a plurality of positioning signals from a plurality of sources deployed in a manner that is structurally independent of the or each seismic sensor, the positioning signals being distinguishable from the seismic survey signal;

receiving the positioning signals at the or each seismic sensor concurrently with the seismic survey signal; and

determining the position of the or each seismic sensor from the received positioning signals.

20. A method as claimed in claim 19, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency outside the frequency range of the seismic survey signal.

21. A method as claimed in claim 20, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency above the frequency range of the seismic survey signal.

22. A method as claimed in claim 21, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency between 700 Hz and 4500 Hz.

23. A method as claimed in claim 22, wherein transmitting the plurality of positioning signals comprises transmitting a plurality of sweeps from 700 Hz to 2000 Hz.

24. A method as claimed in claim 22, wherein transmitting the plurality of positioning signals comprises transmitting a plurality of sweeps from 1500 Hz to 4500 Hz.

25. A method as claimed in claim 19, wherein determining the position of the or each seismic sensor using the received signals comprises determining a plurality of propagation times from the sources to the or each seismic sensor using the received signals.

26. A method as claimed in claim 25, wherein determining the position of the or each seismic sensor comprises determining the position of the or each seismic sensor using the plurality of propagation times.

27. A method as claimed in claim 26, wherein determining the position of the or each seismic sensor using the plurality of propagation times comprises determining the position of the or each seismic sensor by triangulation using the plurality of propagation times.

28. A method, comprising:

transmitting a plurality of positioning signals from a plurality of sources, the positioning signals being distinguishable from a seismic survey signal;

receiving, concurrently with the seismic survey signal, the positioning signals at a plurality of seismic sensors deployed on a sea bed; and

determining the position of the seismic sensors from the received positioning signals.

29. A method as claimed in claim 28, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency outside the frequency range of the seismic survey signal.

30. A method as claimed in claim 29, wherein determining the position of the seismic sensors using the received signals comprises determining a plurality of propagation times from the sources to the seismic sensors using the received signals.

31. A system, comprising:

a vessel;

an ocean bottom seismic cable having at least one seismic sensor capable of receiving a seismic survey signal concurrently with a positioning signal that is distinguishable from the seismic survey signal, wherein the seismic cable is deployed from the vessel;

a plurality of buoys;

a plurality of sources adapted to provide the positioning signal, at least one source being suspended beneath the survey vessel and the remainder being deployed on the buoys; and

a signal processing unit adapted to determine the position of the or each seismic sensor from a positioning signal received at the or each seismic sensor.

32. A system as claimed in claim 31, wherein the buoys are autonomous self-propelled buoys.

33. A system as claimed in claim 31, wherein the buoys are towed behind the survey vessel.

34. A system, comprising:

a vessel;

an ocean bottom seismic cable having at least one seismic sensor capable of receiving a seismic survey signal concurrently with a positioning signal that is distinguishable from the seismic survey signal, wherein the seismic cable is deployed from the vessel;

at least one boom coupled to the vessel;

a plurality of sources adapted to provide the positioning signal, at least one source being coupled to the vessel and the remainder being coupled to the at least one boom; and

a signal processing unit adapted to determine the position of the or each sensor from a positioning signal received at the or each seismic sensor.

35. A system as claimed in claim 34, further comprising an array of seismic cables having at least one sensor capable of receiving the seismic survey signal.

36. A system, comprising:

at least one seismic sensor deployed on an ocean bottom cable and capable of receiving a seismic survey signal concurrently with a positioning signal that is distinguishable from the seismic survey signal;

a plurality of autonomous self-propelled buoys; and

a plurality of sources coupled to the self-propelled autonomous buoys, the sources being adapted to provide, to the or each seismic sensor, the positioning signal.

37. The system as claimed in claim 36, wherein the sources are suspended beneath the autonomous self-propelled buoys.

38. A system as claimed in claim 36, further comprising a signal processing unit adapted to determine the position of the or each seismic sensor using a positioning signal received at the or each seismic sensor.

39. A system, comprising:

a first vessel;

an ocean bottom seismic cable having at least one seismic sensor capable of receiving a seismic survey signal concurrently with a positioning signal that is distinguishable from the seismic survey signal, wherein the seismic cable is deployed from the first vessel;

a second vessel;

a plurality of buoys;

a plurality of sources adapted to provide a positioning signal, at least one source being coupled to the first vessel, at least one source being coupled to the second vessel, and the remainder being deployed on the buoys; and

a signal processing unit adapted to determine the position of the or each seismic sensor from a positioning signal received at the or each seismic sensor.

40. A system as claimed in claim 39, wherein at least a portion of the buoys are deployed along a length of the seismic cable.

41. A system as claimed in claim 40, further comprising an array of seismic cables having at least one seismic sensor capable of receiving the seismic survey signal.

42. A system as claimed in claim 41, wherein at least a portion of the buoys are deployed among the array of seismic cables.

Remote User

[redacted]

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12 pages

MARKS & CLERK

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date 7 March 2003

Dear Ms Sowell

MLS VW 4.24.03
email xc VV DSF

British Patent Application No. 0223673.5
Method and Apparatus for Positioning of Seismic Sensing Cables

Search Report

The UK Patent Office has now issued the official search report on the above application, and this is enclosed. A copy of each document cited in the search report is also enclosed.

You will see that each document has been cited in Category X. This indicates that the Search Examiner considers that each document can be used to attack the novelty and inventive step of the claims.

Please let me know if you would like me to review the citations and comment on their relevance.

Corresponding patent protection in other countries

MLS
Cal

The Convention Year for this (non-priority) application expires on 11 October 2003. Please let me know if good time before this due date if you would like me to file any corresponding applications in other countries.

Further prosecution of this application

MLS
Cal

In order to maintain this application we must file formal drawings no later than 11 January

M 15 ✓
CAL

2004. We must also advise the Patent Office how the applicant derived the right to apply from the inventors, and we must supply this information by no later than 11 February 2004.

Provided that the above matters are dealt with in due time, this application will be published on or soon after 11 April 2004, which is 18 months from the filing date of this application. The fee for substantive examination must be then be paid within six months from the date of publication of the application.

It is now possible to file amendments to the application. Please let me know if you would like to file any amendments at this time.

Please let me know if you require any further information or advice concerning this application. Our debit note in this matter is being sent to WesternGeco AS.

Yours sincerely

Dr Andrew Suckling

Cc Vincent Vicugue Esq (letter only)

The Patent Office

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Your Reference: AMS.P52304GB
Application No: GB 0223673.5

10 February 2003

Dear Sirs

Patents Act 1977: Search Report under Section 17(5)

I enclose two copies of my search report and a copy of the citations.

Publication

I estimate that, provided you have met all formal requirements, preparations for publication of your application will be completed soon after **2 March 2004**. You will then receive a letter informing you of completion and telling you the publication number and date of publication.

Amendment/withdrawal

If you wish to file amended claims for inclusion with the published application, or to withdraw the application to prevent publication, you must do so before the preparations for publication are completed. **No reminder will be issued.** If you write to the Office less than 3 weeks before the above completion date, please mark your letter prominently: **"URGENT - PUBLICATION IMMINENT".**

Yours faithfully

Robert C Mumford
Examiner

[1]**Use of E-mail:** Please note that e-mail should be used for correspondence only.

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 0223673.5	**Examiner:**	Robert C Mumford
Claims searched:	All	**Date of search:**	7 February 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1 - 30.	GB 2089043 A	(CHEVRON RESEARCH) see whole document.
X	1 - 31 & 33.	WO 84/03153 A	(KONGSBERG) seefigs 1 - 4 & page 2 paragraph 4 - page 5 paragraph 1.
X	1 - 31 & 33.	FR 002772931 A	(CIE GENERALE) see abstract and fig 1.
X	1 - 8, 10 12 & 19 - 27	FR 002772134 A	(AQASS) see abstract and figs 1 & 3.
X	1 - 31 & 33.	US 4845686 A	(BRAC) see whole doc esp figs 1 & 2.
X	1 - 30.	US 4635236 A	(ROBERTS) see whole document.
X	1 - 30.	US 4555779 A	(ROBERTS) see whole document.

Categories

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{V}:

G1G

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

G01V, G01S

The following online and other databases have been used in the preparation of this search report.

Online WPI, EPODOC, JAPIO

(12) UK Patent Application (19) GB (11) 2 089 043 A

(21) Application No 8136889
(22) Date of filing 8 Dec 1981
(30) Priority date
(31) 215195
(32) 10 Dec 1980
(33) United States of America (US)
(43) Application published 16 Jun 1982
(51) INT CL³ G01S 5/18
(52) Domestic classification G1G 1G1 1G2 6 7P RA
(56) Documents cited None
(58) Field of search G1G

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(54) Determination of the Location of a Submerged Marine Seismic Streamer

(57) The determination of the location of a submerged marine streamer 20 towed behind a seismic exploration vessel is effected by means of an array of at least three transponders 10, 12, 14 secured to the ocean floor which generate distinguishable acoustic pulses upon a command signal from the ship. These signals are received by acoustic receivers 34 housed in the streamer and by the ship. The distance to each acoustic receiver may be triangulated from the data generated.

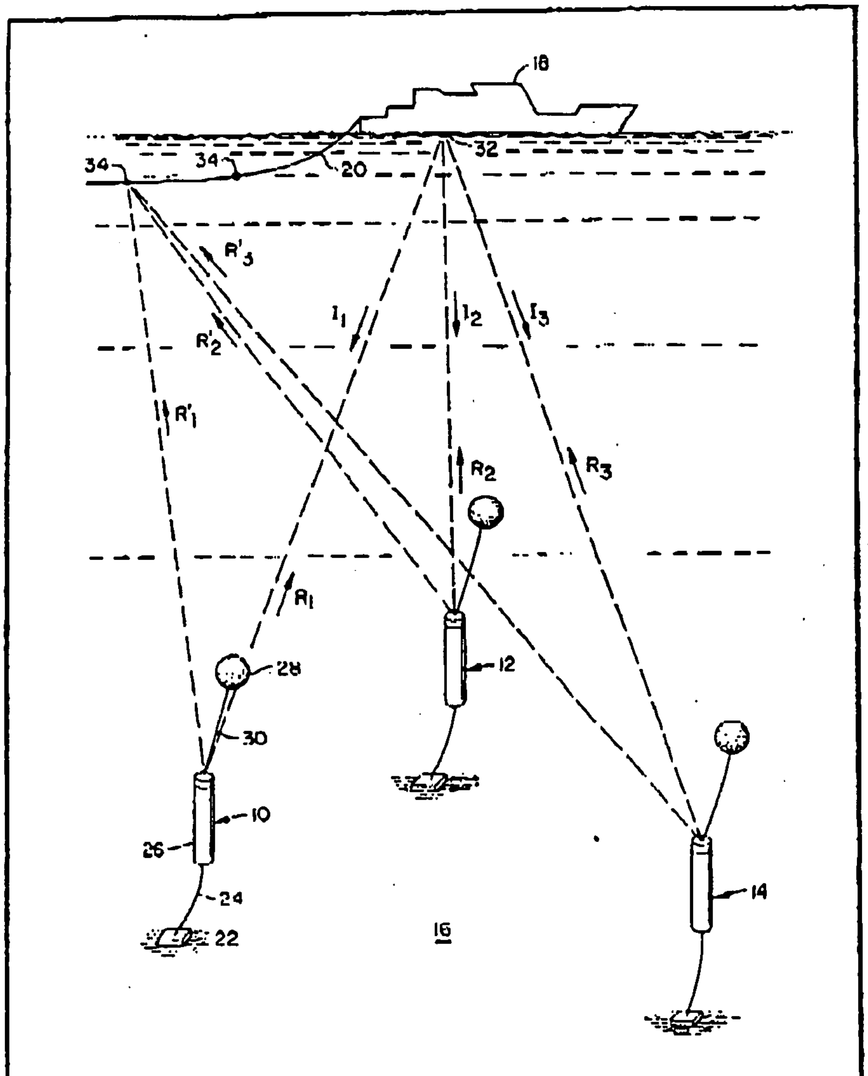

FIG.—1.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 089 043 A

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 3 : G01V 1/38

A1

(11) International Publication Number: WO 84/ 031

(43) International Publication Date: 16 August 1984 (16.08.8

(21) International Application Number: PCT/NO84/00007

(22) International Filing Date: 1 February 1984 (01.02.84)

(31) Priority Application Number: 830358

(32) Priority Date: 2 February 1983 (02.02.83)

(33) Priority Country: NO

(71) Applicant *(for all designated States except US)*: A/S KONGSBERG VÅPENFABRIKK [NO/NO]; Kirkegaardsveien, N-3600 Kongsberg (NO).

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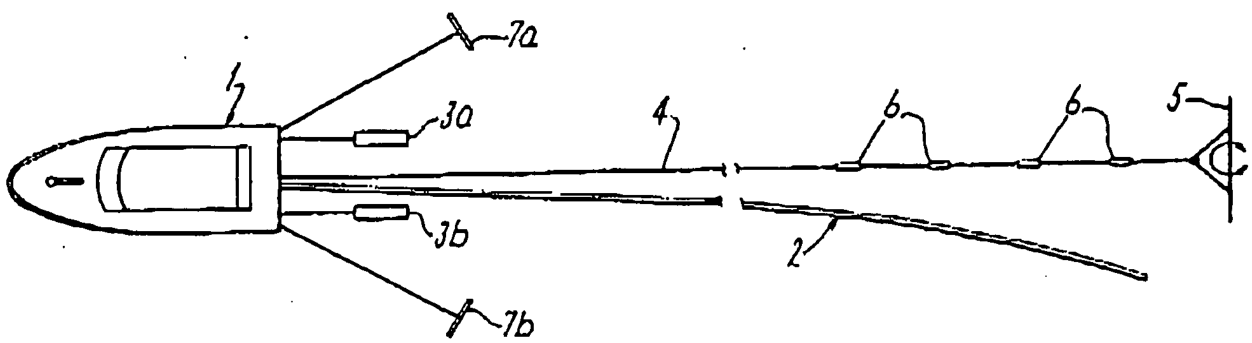
(74) Agent: ONSAGERS PATENTKONTOR AS; Camilla Colletts vei 4, N-Oslo 2 (NO).

(81) Designated States: AU, BR, DE, DE (European patent), FR (European patent), GB, GB (European patent), JP, NL, NL (European patent), SU, US.

Published
With international search report.
In English translation (filed in Norwegian).

(54) Title: DEVICE IN A HYDROPHONE CABLE FOR MARINE SEISMIC SURVEYS



(57) Abstract

A device in a hydrophone cable which in connection with seismic surveys is towed through the water behind a ve sel, the hydrophone cable comprising means for detecting echo signals which are reflected from the sea bed and variou layers therebelow. For the purpose of improving the determination of the position of the hydrophone cable which ca have a length of approx. 3000 meters, a transmission system is suggested, which comprises transmission elements arrange outside the hydrophone cable itself, the transmission elements serving to determine the position of the hydrophone cab in relation to the elements. In a simple embodiment of the device according to the invention the transmission elements ar attached to or are constituted by a separate towing line (4) having a relatively small diameter, the towing line bei equipped with stretching means (5) for achieving a relatively straight run. In an alternative embodiment the transmissic elements can be implemented as reflectors (9a-9n) for preferably electromagnetic waves, for example in the form of ligl gas-filled balloons which can be attached to the hydrophone cable via thin, light lines, so that the balloons can be towed surface position or fairly high above the water surface. The transmission elements can also be included in a convention radio and navigation system, possibly together with the system used by the towing vessel for its positioning, in addition determination of distance and bearing by means of the radar system of the vessel. The transmission elements can also b included as elements in an adaptive control system for combined control of vessel and hydrophone cable.

PN - FR2772931 A 19990625

PD - 1999-06-25

PR - FR19970016497 19971224

OPD - 1997-12-24

TI - System for monitoring the placement of a seismic cable, from a ship, onto the sea bed.

AB - The seismic cable includes a number of acoustic transmitters spread along it each of which transmits an identifiable acoustic signal. The system includes a floating network having at least three acoustic receiver units (T,B,Q), with means for knowing the position of these units (T,B,Q) with respect to the ship (V). The system has also means for transmitting to a processing unit the time corresponding to receipt, by the receiver units (T,B,Q), of signals from the acoustic cable transmitters (P). The processing unit includes means for calculating, from these time and position values the position of the acoustic transmitters and therefore the trajectory of the cable as it is unrolled from the ship.

IN - BOUCQUAERT FRANCOIS;LECOQ FREDERIC

PA - GEOPHYSIQUE CIE GLE (FR)

EC - G01V1/38C

IC - G01V1/38

CT - US5497356 A [Y]; EP0308222 A [A]; EP0267840 A [A]; FR2620536 A [A]; XP000312715 A [Y]

CTNP - [Y] BELL B M ET AL: "NONLINEAR KALMAN FILTERING OF LONG-BASELINE, SHORT-BASELINE, GPS, AND DEPTH MEASUREMENTS" PROCEEDINGS OF THE ASILOMAR CONFERENCE ON SIGNALS, SYSTEMS AND COMPUTERS, PACIFIC GROVE, NOV.4 - 6, 1991, vol. 1, no. CONF. 25, 4 novembre 1991, pages 131-136, XP000312715 CHEN R R

TI - System for monitoring the placement of a seismic cable, from a ship, onto the sea bed.

PR - FR19970016497 19971224

PN - FR2772931 A1 19990625 DW199938 G01V1/38 012pp

PA - (GEOP-N) CIE GEN GEOPHYSIQUE

IC - G01V1/38

PN - FR2772134 A 19990611

PD - 1999-06-11

PR - FR19970015484 19971208

OPD - 1997-12-08

TI - Device for executing combined hydrographic surveys from one vessel

AB - The differential GPS, terrestrial GPS, the hydrographic sounder, and information processing device are chosen to have small dimensions and are combined in a portable box. They are arranged in the box so that they function without modification. An opening (12,13) in the box provides for the removal of the acoustic base of the hydrographic sounder and to activate the various equipment. Device comprises a differential GPS receiver (3) equipped with HF, UHR or VHF communication for positioning by satellite, a terrestrial GPS (8) station with HF, UHF or VHF communication (9), a hydrographic sounder (2) and its acoustic base (11) and a computer device (4) for processing data.

IN - CHAUMET LAGRANGE MARC

PA - AQASS (FR)

EC - G01C13/00 ; G01S5/14B3 ; G01S5/14B4 ; G01V1/38C

IC - G01S5/14 ; G01C7/00 ; G01C13/00

CT - WO9704334 A [X]; DE29618253U U [A]; US5689475 A [A]; US5559754 A [A]; JP9053936 A [A]

CTNP - [A] PATENT ABSTRACTS OF JAPAN vol. 097, no. 006, 30 juin 1997 &
JP 09 053936 A (UNYUSHO DAISAN KOWAN KENSETSU KYOKUCHO;FURUNO ELECTRIC CO LTD),25 février 1997

TI - Device for executing combined hydrographic surveys from one vessel

PR - FR19970015484 19971208

PN - FR2772134 A1 19990611 DW199936 G01S5/14 010pp

PA - (AQAS-N) AQASS EURL

IC - G01C7/00 ;G01C13/00 ;G01S5/14

IN - CHAUMET L M

AB - FR2772134 NOVELTY - The differential GPS, terrestrial GPS, the hydrographic sounder, and information processing device are chosen to have small dimensions and are combined in a portable

United States Patent [19]
Brac

[11] Patent Number: 4,845,686
[45] Date of Patent: Jul. 4, 1989

[54] METHOD AND DEVICE FOR DETERMINING THE POSITION OF IMMERSED OBJECTS WITH RESPECT TO THE SHIP WHICH TOWS THEM

[75] Inventor: Jean Brac, Saujon, France

[73] Assignee: Institut Francais du Petrole, Rueil-Malmaison, France

[21] Appl. No.: 112,942

[22] Filed: Oct. 27, 1987

[30] Foreign Application Priority Data

Oct. 31, 1986 [FR] France 86 15309

[51] Int. Cl.⁴ G01V 1/38
[52] U.S. Cl. 367/130; 367/19
[58] Field of Search 367/106, 130, 19, 2, 367/6, 16-18, 20; 114/242

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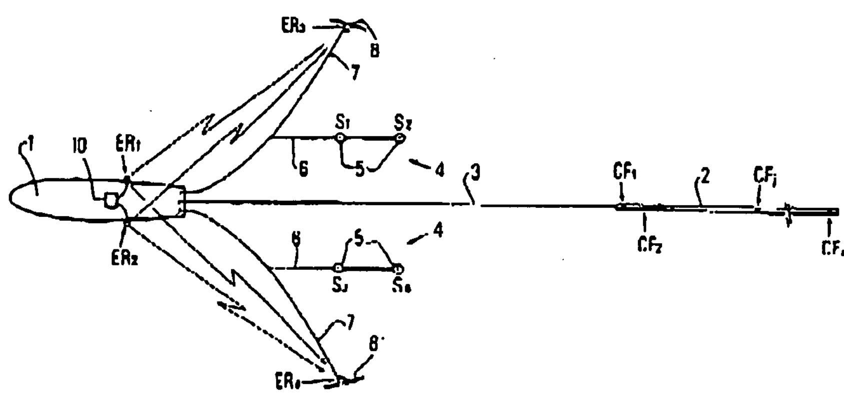
2113391 8/1983 United Kingdom

Primary Examiner—Thomas H. Tarcza
Assistant Examiner—Daniel T. Pihulic
Attorney, Agent, or Firm—Antonelli, Terry & Wands

[57] ABSTRACT

A method and device are provided for determining by acoustic telemetering the position of immersed objects with respect to a ship having a location assembly connected thereto including two acoustic transmission-reception assemblies and a towed locating base including two other assemblies offset laterally with respect to the path of the ship, in which method two measuring cycles are carried out successively, the first one consisting in determining by acoustic telemetering the position of the mobile locating base with respect to the locating base fixed to the ship, while the second consists, still using acoustic telemetering, in determining the position of the towed objects with respect to the mobile locating base. Then the coordinates of all the towed objects are determined with respect to the ship.

10 Claims, 5 Drawing Sheets



United States Patent [19]
Roberts

[11] Patent Number: 4,635,236
[45] Date of Patent: * Jan. 6, 1987

[54] SUBMERGED MARINE STREAMER LOCATOR

[75] Inventor: F. Alex Roberts, Brea, Calif.

[73] Assignee: Chevron Research Company, San Francisco, Calif.

[*] Notice: The portion of the term of this patent subsequent to Nov. 26, 2002 has been disclaimed.

[21] Appl. No.: 637,445

[22] Filed: Aug. 3, 1984

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 306,795, Sep. 29, 1981.

[51] Int. Cl.[4] G01S 15/06; G01V 1/38
[52] U.S. Cl. 367/19; 367/6; 367/130
[58] Field of Search 367/6, 16, 19, 20, 106, 367/130, 117; 181/110

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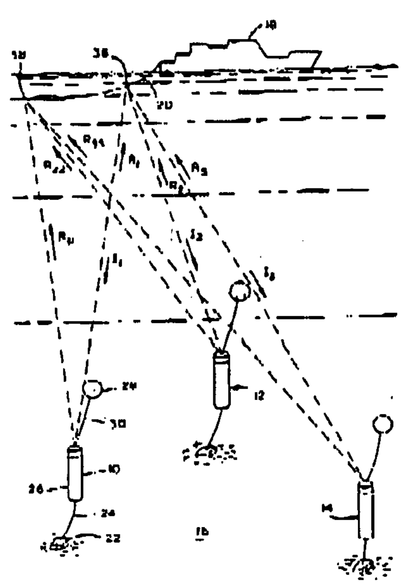
Primary Examiner—Nelson Moskowitz
Assistant Examiner—Gregory C. Issing
Attorney, Agent, or Firm—S. R. LaPaglia; E. J. Keeling, P. L. McGarrigle

[57] ABSTRACT

Method and means are provided for determining the position of a submerged marine streamer towed behind an exploration vessel. An array of sets of at least three transponders secured to the ocean floor generate distinguishable acoustic pulses upon a command signal. These signals are received by receivers housed in the streamer. The position to each receiver may be triangulated from the data generated.

7 Claims, 2 Drawing Figures



United States Patent [19]

Roberts

[11] Patent Number: 4,555,779

[45] Date of Patent: Nov. 26, 1985

[54] SUBMERGED MARINE STREAMER LOCATOR

[75] Inventor: F. Alex Roberts, Brea, Calif.

[73] Assignee: Chevron Research Company, San Francisco, Calif.

[21] Appl. No.: 476,690

[22] Filed: Mar. 18, 1983

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 215,195, Dec. 10, 1980, abandoned.

[51] Int. Cl.[4] G01S 15/06; G01V 1/38

[52] U.S. Cl. 367/19; 367/6, 367/130

[58] Field of Search 367/19, 6, 106, 117, 367/130, 181/110; 455/40; 375/6

[56] **References Cited**

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4,229,809	10/1980	Schwalbe	367/6

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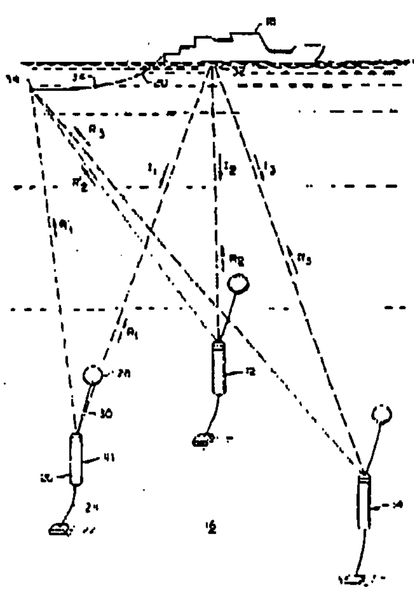
"Dynamic Positioning System for . . .", by H. W. Rugland, Honeywell Inc., pp. 1145-1161.

Primary Examiner—Nelson Moskowitz
Assistant Examiner—Ian J. Lobo
Attorney, Agent, or Firm—D. A. Newell; E. J. Keeling; P. L. McGarrigle

[57] **ABSTRACT**

Method and means are provided for determining the position of a submerged marine streamer towed behind an exploration vessel. An array of at least three transponders secured to the ocean floor generate distinguishable acoustic pulses upon a command signal from the ship. These signals are received by hydrophones housed in the streamer and by the ship. The distance to each hydrophone may be triangulated from the data generated including accounting for changes in velocity between the vessel and the seismic streamer and the bottom transponders during the taking of such data

10 Claims, 2 Drawing Figures



Remote User

[redacted]

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20 pages

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Your Reference: AMS.P52304GB
Application No: GB0223673.5

8 June 2005

Dear Sirs

Patents Act 1977: Examination Report under Section 18(3)

Latest date for reply: **10 October 2005**

I enclose two copies of my examination report and a copy of the new citations.

By the above date you should either file amendments to meet the objections in the enclosed report or make observations on them. If you do not, the application may be refused.

Yours faithfully

Stephen Jennings
Examiner

[1]**Use of E-mail:** Please note that e-mail should be used for correspondence only.

The Patent Office
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Your ref :	AMS.P52304GB	Examiner :	Stephen Jennings
Application No:	GB0223673.5	Tel :	01633 814986
Applicant :	WesternGeco Seismic Holdings Limited	Date of report :	8 June 2005
Latest date for reply:	10 October 2005	Page 1/6	

Patents Act 1977
Examination Report under Section 18(3)

Novelty (Section 1(1)(a))

1. The invention as defined in claims 1-4,7-12,19-21,25-27 is not new because it has already been disclosed in each of the following documents:

US 4,376,301* (Roberts) relevant to claims 1-4,7,9-12,19-21,25-27
WO 84/03153 (Kongsberg Vapenfabrikk) relevant to claims 1,7-8,10,19

* I apologise for citing a new document at this stage. You will be aware that this document is listed on the search report for your equivalent PCT application WO2004034091.

2. US 4,376,301 relates to an apparatus and method for determining the location of a marine streamer towed behind an exploration vessel. As shown in figure 1 the apparatus includes a plurality of hydrophones 20 spaced along the streamer. I consider these hydrophones to be seismic sensors. The apparatus also includes at least a pair of sources (shown at 28,30 in figure 1) which transmit high frequency sound pulses. These high frequency sound pulses, which would clearly be distinguishable from the seismic survey signals, are received by the hydrophones and the received signals are used to determine the position of the hydrophones. US 4,376,301 shows that the invention, as defined in independent claims 1 and 19, is not new.

3. Claims 2-4 and 20-21 lack novelty in view of column 3 lines 36-38 of US 4,376,301.

4. Claim 7 lacks novelty, as figure 1 of US 4,376,301 clearly illustrates two sources.

5. Column 3 lines 42-45 of US 4,376,301 states that the sources may be piezoelectric sources, thus indicating lack of novelty in claim 9.

6. US 4,376,301 also shows a lack of novelty in claims 10-12 and 25-27. Whilst the method of determining the position of the seismic sensors (hydrophones) is somewhat different to that described in your application, the method is still based on using a plurality of propagation times from the sources to the sensors (as described at column 3 lines 17-27) and may be considered as a triangulation method (as indicated at column 4 lines 35-40).

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Your ref : AMS.P52304GB
Application No : GB0223673.5

Date of report: 8 June 2005
Page 2 / 6

[Examination Report contd.]

7. WO 84/03153 describes an apparatus and method for determining the position of a hydrophone cable towed behind a vessel. As shown in figures 1 and 2, the apparatus includes a series of acoustic signal generators (6, 7a & 7b or 8a-8n) which generate signals which are detected by the hydrophones in the hydrophone cable 2. I understand these hydrophones to be the sensors which are used in conducting the seismic survey, i.e. the seismic sensors. The signals received by the hydrophones are used to determine the shape and position of the hydrophone cable relative to the vessel. As indicated at page 8 lines 10-15, the signals received by the hydrophones are of frequencies and types which make them easily recognisable, which I take to mean that the signals are distinguishable from the seismic survey signals. WO 84/03153 demonstrates a lack of novelty in independent claims 1 and 19.

8. It is not entirely clear how many signal generators are envisaged for the apparatus described in WO 84/03153, but figure 1 shows four such devices 6. On the face of it, therefore, claims 7 and 8 lack novelty. Even if claims 7 and 8 were found to be novel over WO 84/03153 they would attract an inventive step objection.

9. WO 84/03153 clearly shows a lack of novelty in claim 10.

Inventive step (Section 1(1)(b))

10. The invention as defined in claims 1-13,19-22,25-28,30 is obvious in view of what has already been disclosed in the following documents:

US 4,376,301* (Roberts) relevant to claims 5-6,22
WO 84/03153 (Kongsberg Vapenfabrikk) relevant to claims 2-6,9,11-12,20-22,25-27
US 4,641,287* (Neeley) relevant to claims 1,7-13,19,25-28,30

* I apologise for citing these documents at this stage. You will be aware that these documents are listed on the search report for your equivalent PCT application WO2004034091.

11. The positioning signals in US 4,376,301 take the form of pulses preferably having frequencies in the range of 2-100 kHz. The skilled person would realise, without exercising inventive ingenuity, that other frequencies outside the frequency range of the seismic survey could equally be used, such as those specified in claims 5-6 and 22 of the current application. These claims do not introduce an inventive step over US 4,376,301.

12. Page 8 lines 10-15 of WO 84/03153 states that the signals received by the hydrophones are of frequencies and types which make them easily recognisable. The skilled man would readily appreciate that one means of achieving this would be to use high

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frequencies, that is frequencies outside the range of the seismic survey. Use of high frequency acoustic signals in streamer positioning is known from US 4,376,301, for example. Accordingly claims 2-3 and 20-21 lack inventive step in the light of WO 84/03153. Furthermore there appears to be no inventive merit in claims 5-6 and 22, which merely specify a particular operating frequency.

13. WO 84/03153 does not provide much detail as to how the position of the hydrophone cable is determined from the signals received at the hydrophones from the acoustic signal generators. However, position determination using transit time and triangulation is well known in the art. Accordingly claims 11-12 and 25-27 are obvious in the light of WO 84/03153.

14. US 4,641,287 describes a system and method for determining the position of seismic sensors on an ocean bottom cable. As illustrated in figure 1, the ocean bottom cable includes a plurality of acoustic pulse detectors 24, which I understand to be the seismic sensors used in conducting a seismic survey. Acoustic pulses S, S+1, S+2, S+3 are generated at a number of shot locations and the travel time of these acoustic pulse to the detectors is used to determine the position of the detectors. Though not explicitly stated in the document, it is implicit that the described method for locating the ocean bottom cable would be performed independently of a seismic surveying operation, for example during a period when a seismic survey was not being conducted. The signals received at the detectors would therefore distinguishable from seismic survey signals, even though they might take the same form. Though US 4,641,287 only shows one acoustic source 38 fired at a plurality of positions, it would be obvious to the person skilled that the same result could be achieved using a plurality of sources. Using a plurality of spaced sources in a system and method for determining the position of a seismic cable is known in the art. Such arrangements are shown in WO 84/03153 and US 4,376,301 mentioned above, and also in GB 2,089,043, US 4,555,779 and US 4,635,236 mentioned on the search report. US 4,641,287 shows that the invention, as defined in independent claims 1,13,19 and 28, lacks an inventive step.

15. In view of the above comments, dependent claims 7-12,25-27 and 30 also lack inventive step in view of the teaching of US 4,641,287. The method disclosed therein clearly uses the propagation times from the sources to the detectors, and might be described as a triangulation method.

Clarity, Conciseness, Support and Plurality (Section 14(5))

16. Your patent application includes numerous independent claims that have slightly different but overlapping scopes. Such a set of claims is not concise, casts doubt on the

[Examination Report contd.]

essential features of the invention and places an undue burden on a reader attempting to understand the full scope of the claimed monopoly.

17. The *Code of Practice for patent applicants and agents* includes the following 'best practice' guidance:

The claims as filed should not, where it might have been avoided, contain...multiple independent claims in any one category, even if only one inventive concept is present

You may also wish to refer to paragraphs 14.110.1 and 14.140 of the *Manual of Patent Practice,* which are particularly relevant to this issue.

18. I am not formally objecting to plurality at this stage but I am of the opinion that your claims relate to a plurality of inventions, though it is unclear how many inventive concepts are present. The common matter of the eight independent claims is: an apparatus comprising at least one seismic sensor and plurality of sources which provide a positioning signal distinguishable from the seismic survey signal, or a method which uses such an apparatus. This common subject matter is clearly disclosed in a number of the documents mentioned on the search report.

19. You should therefore consider amending your claims to define the essential features of your invention using a single independent claim for each category (eg product, process, apparatus, use), leaving non-essential features to dependent claims, and thus ensuring that your claims relate to a single inventive concept.

20. It is clear from claim 1 that the sources generate positional signals which are distinguishable from the seismic survey signals, but the construction of lines 5-7 of the claim means that it is not clear whether these positional signals are provided to the seismic sensors. In contrast, claims 13,19,28 make clear that the sources provide a positional signal to the seismic sensors.

21. The phrase 'deployed in a manner structurally independent of' in claims 1 and 19 is unclear. If, as indicated at page 7 lines 22-24, you mean that there is no known relationship between the position of the sources and the seismic sensor then you should say so more clearly.

22. Claim 1 specifies that the apparatus comprises 'at least one seismic sensor', which includes the case of *only* one seismic sensor, but the claim later refers to seismic sensors in the plural. To ensure clarity you may wish to consider amending the end of claim 1 along the lines of '...a seismic signal to the **or each** seismic sensor'. A similar comment applies to claims 13,19,31,34 and 39.

23. It is not clear what is meant by the use of the term 'bandwidth' in claims 2-6,14-18, 20-21 and 29. The term is generally taken to mean the spread of a range of frequencies, i.e. the difference between the upper and lower frequencies of a range of frequencies. Using such a definition, claim 5, for example, means that the bandwidth of the positioning signals is between 700 and 2000 Hz, but the claim does not indicate the lower and upper bounds of the frequency range of the signals. Such a definition means that the claims are at odds with the description. As I understand the description, positioning signals are provided which have a range of frequencies which does not overlap with the range of frequencies of the seismic survey, the range of frequencies being 700-2000 Hz or 1500-4500 Hz, for example. You should therefore consider amending claims 2-6,14-18 and 20-24 to use the term 'frequency range' rather than 'bandwidth'.

24. The term '*the* received positioning signals', at the end of claim 31, is not mentioned earlier in the claim. A similar objection relates to claims 34 and 39. These claims do not specify that the positioning signals are received by the seismic sensor(s).

25. Claims 31,34,35 and 39 do not require that the positioning signals are received by the seismic sensors. As I understand it, this is an essential feature of your invention, as set out in the 'summary of invention' on page 3 at lines 13-16 and 22-24, and mentioned at page 7 lines 6-8, page 8 lines 22-24 and page 13 lines 4-5. I can see no enabling disclosure in the description of the positioning signals being received at any sensors other than those provided on the streamer cable for detecting seismic survey signals. Accordingly claims 31,34,35 and 39 are not supported across their entire width.

26. Page 7 lines 10-12 states that some embodiments of your invention may use optical or radar signals, or the like, instead of acoustic signals. Such embodiments certainly fall outside the scope of claims 1,13,19 and 28 as currently presented. You should ensure, on amendment, that your description does not describe any embodiments falling outside the scope of your claims, so that no doubt is cast on the scope of your invention.

27. Claim 18 is inconsistent with claim 17, upon which it depends. Perhaps claim 18 should be appended to claim 16, not claim 17.

28. It is not clear what, if anything, claim 26 adds to claim 25.

29. There are two claims numbered '34'. Some amendment of the claim numbering is clearly required.

30. The term 'the received signals' in claim 37 has no antecedent basis in claim 35.

[Examination Report contd.]

Non-metric units

31. The equivalent metric values should be given alongside the non-metric values mentioned on page 1 of your specification.

Other matters

32. The references to 'spirit' of the invention on pages 5 and 15 should be deleted.

United States Patent [19] [11] **4,376,301**

Roberts [45] **Mar. 8, 1983**

[54] **SEISMIC STREAMER LOCATOR**

[75] Inventor: **F. Alex Roberts**, Brea, Calif.

[73] Assignee: **Chevron Research Company**, San Francisco, Calif.

[21] Appl. No.: **215,207**

[22] Filed: **Dec. 10, 1980**

[51] Int. Cl.³ G01V 1/38

[52] U.S. Cl. 367/19; 367/130; 367/117

[58] Field of Search 367/19, 106, 117, 130, 367/907; 455/40; 375/6; 73/597, 610

[56] **References Cited**

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4,064,479	12/1977	Ruehle	340/7 R
4,068,208	1/1978	Rice et al.	340/7 R
4,087,780	5/1978	Itria	367/19
4,138,657	2/1979	Shave	340/3 D
4,211,300	7/1980	Miller	181/120
4,229,809	10/1980	Schwalbe	367/106
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Leroy et al., "Acoustic Measuring System . . .", 5/8/74, pp. 849-863, OTC, vol. I, #2026.

Rogland, "A Dynamic Positioning System . . ." 1965, pp. 1145-1161, Honeywell Inc.

Sherwood, "Acoustic Navigation Systems", 6/64, pp. 22-24, Undersea Technology.

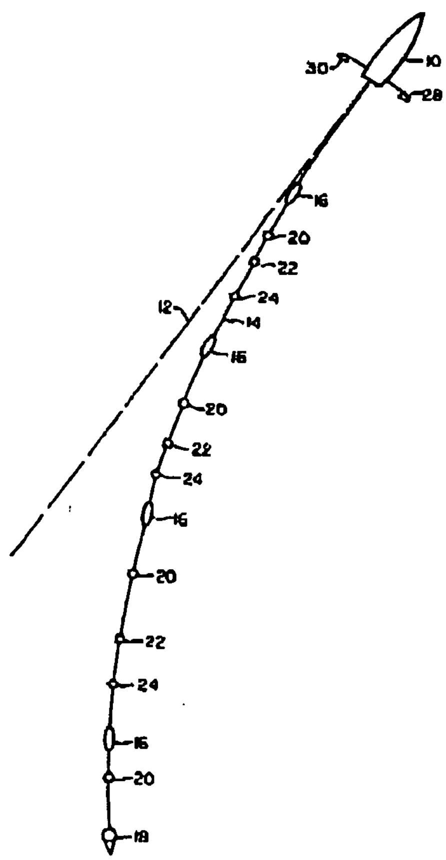
Primary Examiner—Nelson Moskowitz

Attorney, Agent, or Firm—D. A. Newell; E. J. Keeling

[57] **ABSTRACT**

Method and means are provided for determining the position of a submerged marine streamer towed behind an exploration vessel. A sonic ring around feedback system is employed to redundantly ascertain the distance to various hydrophones housed in the streamer from an outboard mounted transponder capable of generating high frequency sound pulses of short duration.

9 Claims, 2 Drawing Figures



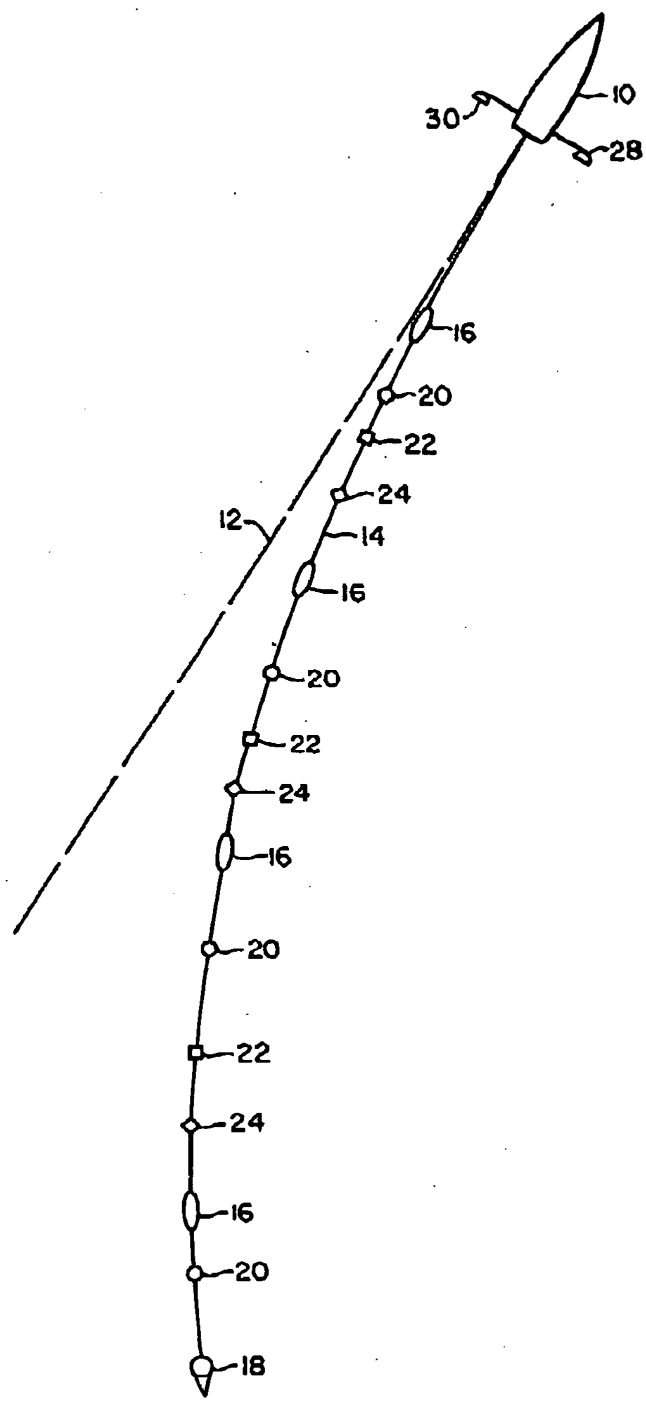


FIG._1.

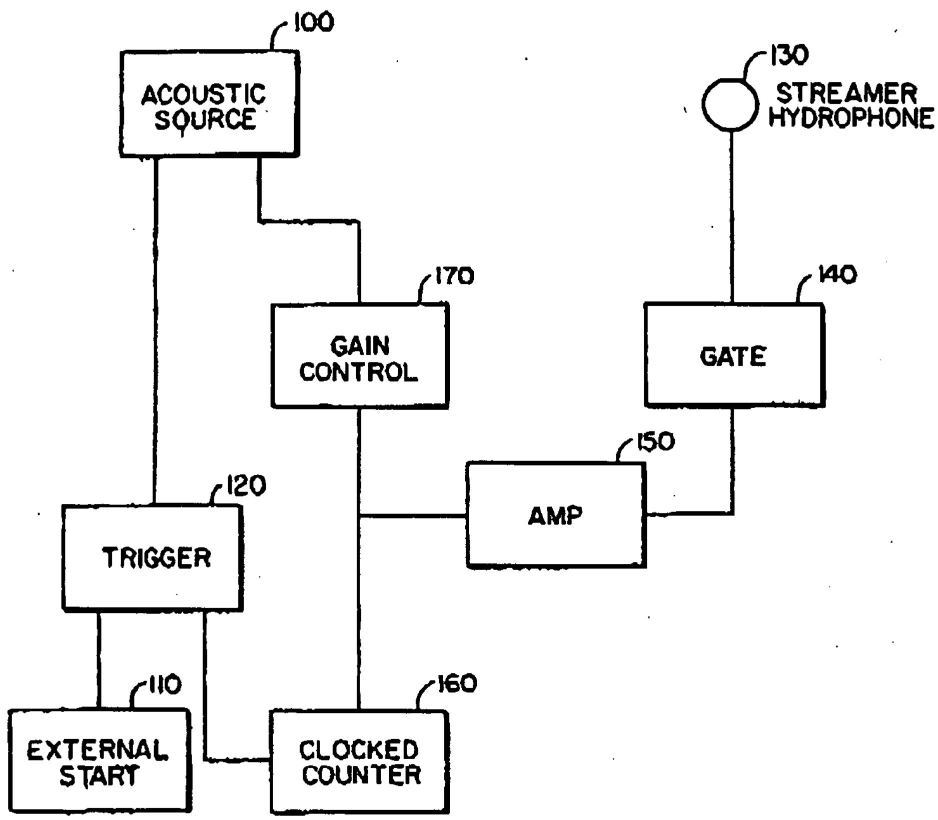

100
ACOUSTIC SOURCE
130
STREAMER HYDROPHONE
170
GAIN CONTROL
140
GATE
150
AMP
120
TRIGGER
110
EXTERNAL START
160
CLOCKED COUNTER

FIG.__2.

SEISMIC STREAMER LOCATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention finds principal application within the field of marine seismic exploration. More particularly, the invention is concerned with a method and means for accurately determining the position of a towed marine seismic streamer.

2. Prior Art

In marine seismic prospecting, an exploration vessel tows a seismic streamer having a plurality of pressure sensitive detectors, commonly referred to as hydrophones. A source of seismic energy, such as an air gun or an explosive charge, is used to propagate pressure waves through the water into the underlying sea floor. Part of the energy will be reflected by subfloor geological discontinuities and subsequently detected by the hydrophones as pressure variations in the surrounding water. The mechanical energy of these pressure variations is transformed into an electrical signal by the hydrophones and transmitted through the streamer to recording apparatus aboard the vessel. The collected data may then be interpreted by those skilled in the art to reveal information about the subsea geological formations.

For the signals to be meaningful, it is necessary to know the precise location of the individual hydrophones at the time the pressure waves are detected. As the vessel is continually moving and as the streamer may extend for thousands of feet behind the vessel, accurate location of hydrophones is difficult.

Various systems have been developed to provide accurate information as to the location of the vessel, however, it is rare for the streamer to trail directly along the path of the vessel. While the streamer is attached to the stern of the vessel, the bulk of the streamer is submerged below the water surface through the action of depth controllers along the length of the streamer. As a result, the cross-track current velocity at the streamer depth may differ from the cross-track current affecting the vessel, thereby causing the streamer to trail at an angle to the vessel's course. Other factors, which are not necessary to enumerate, may also create a variance in the path of the streamer when compared to the vessel track.

One method of estimating the location of the streamer disclosed in the prior art relies upon the addition of a tail buoy radar reflector located at the end of the streamer. On-board radar systems may then be used under optimal sea conditions to find the end of the streamer and the location of the individual hydrophones interpolated. Such systems are generally unreliable however, and render the required data suspect.

A second method taught by the art relies upon very sensitive and expensive apparatus to measure the yaw and pitch angles of the streamer end adjacent the vessel. These data, coupled with magnetic compass headings taken along the streamer and the known depth of the streamer, permits one to empirically calculate the hydrophone locations.

In normal operations, the vessel travels at a speed of approximately 3 meters per second and sets off original seismic propagations approximately every 10 seconds. The use of seismic propagations at a shorter interval is limited by the time required for the dissipation of all reflected seismic waves. In particular, the use of an air

gun at intervals of less than 4 seconds will not permit sufficient dissipation of the sound waves and will result in data that is difficult or impossible to evaluate due to the reflected noise. Thus, the use of an air gun, in combination with the hydrophones for range estimation, presents problems and does not allow for a lack of redundancy in precisely locating the hydrophones.

SUMMARY OF THE INVENTION

The present invention relates to apparatus for use in determining the location of a marine streamer towed behind an exploration vessel. The apparatus includes an acoustic source mounted outboard from the stern of the vessel beneath the water surface which is capable of emitting high frequency sound pulses of short duration upon an external command. A plurality of hydrophones is housed in the streamer capable of receiving pulses from the acoustic source and transmitting signals through separate channels in the streamer in response thereto. To provide redundant measuring capability, a preselected number of hydrophone signals will each trigger additional pulses from the acoustic source. Measurement of the elapsed time from a first externally initiated pulse to the receipt of the last predetermined signal generated by a hydrophone permits an accurate determination of the range.

Preferably, a pair of acoustic sources are mounted apart and outboard from the stern of the vessel which are capable of emitting the high frequency sound pulses. The pair of sources may be used in different time frames to acquire data as to the location of the hydrophones or they may use different frequency pulses which are distinguishable by the hydrophones and in response to which different signals may be returned to the vessel.

It is also preferred to use the return signals from the hydrophones to adjust the amplitude of the acoustic source pulses to minimize the power required for transmission, hence minimizing reverberations.

The frequency of the sounds pulses are preferably in the range between 3.5 and 250 kilohertz and the pulse should normally have a duration running from the time required for a single cycle to approximately 20 cycles.

In one preferred embodiment, all of the hydrophone channels are simultaneously monitored and the acoustic source is triggered into generating additional pulses only after the signal is received responsive to the previous pulse by the last or furthest hydrophone in the streamer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top view of a marine streamer being towed by a vessel.

FIG. 2 is a block circuitry diagram of apparatus suitable for use in the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a diagrammatic representation of an exploration vessel 10 towing a marine seismic streamer as viewed from above. The track of the vessel is indicated by dashed line 12 and the streamer 14 arcuately trails to one side. A plurality of depth controllers 16 of conventional design maintain the bulk of the streamer at a depth beneath the surface of from approximately 5 to 10 meters. Tail buoy 18 is affixed to the trailing end of streamer 14 and maintains the end of the streamer at the surface. A plurality of hydrophones 20 are spaced along

the length of the streamer for detecting pressure variations and transmitting signals announcing the receipt of same along the streamer to recording apparatus aboard the vessel. In addition, the streamer 14 will also house a plurality of depth sensors 22 and magnetic compasses 24 which may be interrogated for information as to the depth and orientation of the streamer at the locations of these instruments.

An air gun 26 is mounted outboard from the stern of vessel 10. In a conventional gun, air, compressed to a pressure in the range, 34 to 350 atmospheres, is suddenly released from a submerged chamber over a period of a few milliseconds to generate an acoustic impulse.

A pair of high frequency acoustic sources, 28 and 30, are mounted outboard from the vessel stern and are typically spaced apart from each other at a distance of 20 to 40 meters. Acoustic sources 28 and 30 generate high frequency pulses of short duration which are received by the hydrophones 20. Upon receipt of the pulses, the hydrophones emit a signal which is transmitted to the vessel along the streamer. The transmitted hydrophone signals are used to trigger additional pulses from the sources 28 and 30 in a controlled oscillation loop. Measurement of the time involved for a given number of oscillations allows redundant, accurate calculations of the distance to the hydrophones, given the velocity of the pulses in water. With the calculated range, location of the hydrophones may be determined precisely in conjunction with the depth data obtained by interrogation of sensors 22.

FIG. 2 illustrates in block form functional circuitry which may be used to accomplish the range-finding objectives stated above. In accordance with FIG. 2, acoustic source 100 is triggered into initiating a pulse, via external start 110 and trigger 120, of high frequency and short duration. The pulse will preferably be in the range, 2 to 100 kilohertz and more preferably in the range, 3 to 10 kilohertz. The pulse length is preferably from monocycle to 20 cycles. Longer pulses may be used but serve no useful purpose. The acoustic source may be piezoelectric, ferroelectric, or electromagnetic in nature. Preferably, the source will comprise a piezoelectric or ferroelectric device having a pencil-shaped acoustic beam oriented in the general direction of the streamer. Such units having a frequency in the range of 2 to 8 kilohertz and capable of generating unit cycle pulses are commercially available.

As mentioned above, the acoustic sources are preferably mounted outboard from the stern of the exploration vessel and are separated by a distance of 20 to 40 meters for triangulation purposes.

The pulse from acoustic source 100 travels through the water at a speed of approximately 1500 meters per second and contacts the streamer hydrophone 130. Hydrophones, such as hydrophone 130, are spaced along the length of the streamer at distances from 100 to 500 meters, and most preferably, at 400 meters. As the pulse is detected, the hydrophone responds and transmits a signal through the streamer to the vessel. Such signals will normally be transmitted along separate electrical conductors extending to each hydrophone. Transmitted signals from the hydrophone pass through a gate 140 which blocks all signals except those that are expected during preselected time intervals. Since the approximate distances from the acoustic sources to the individual hydrophones are known from the spacing of the hydrophones along the streamer, the approximate time "window" for receipt of the signals from the individual hydrophones may be determined. Gate 140 thus serves to block spurious signals generated by reflections from the water surface and ocean floor.

Since the purpose of the present invention is to redundantly determine the location of each hydrophone along the streamer by a ring-around feedback system, the acoustic source must initiate a pulse upon receipt of an incoming hydrophone signal. To prevent the generation of confusing hydrophone signals, each hydrophone is preferably monitored sequentially through individual channels.

The signals passing through gate 140 are amplified and shaped in unit 150. The shaped signals are passed in parallel through a clocked counter 160 and gain control unit 170. The gain control unit automatically adjusts the transmission power of acoustic source 100 in response to the strength of the signals from the amplifier 150 to minimize power consumption. Clocked counter 160 counts the number of feedback signals emanating from the selected hydrophone and times the interval required for a preset number of repetitious signals.

Since the only time lapse of significance is the time required for passage of the acoustic pulse through the water, this time may be repetitiously measured and the average value determined to accurately ascertain the range.

Circuitry is also provided to automatically retrigger an acoustic pulse through trigger 120 in response to the signals passing through counter 160. After a predetermined number of signals, preferably six, have been received, the counter resets to zero to await the beginning of additional range-finding operations for successive hydrophones through external start 110.

Although FIG. 2 depicts only a single acoustic source, it is preferable to use a pair of sources so that independent range determinations may be triangulated to pinpoint the hydrophone position with either the knowledge of the depth or the appropriate compass headings.

If two acoustic sources are employed, they should be alternately used to prevent confusing cross signals or should use differing frequency outputs so that distinguishable signals may be generated by the hydrophones.

In another preferred embodiment, all of the channels from the hydrophones are simultaneously monitored and the receipt of the hydrophone signals are individually timed. However, the acoustic source is triggered into generating a succeeding pulse only after receipt of the incoming hydrophone signal emanated from the last or furthest hydrophone in the streamer.

What is claimed is:

1. Apparatus for use in redundantly determining the position of a seismic marine streamer towed directly behind the stern of a vessel, which comprises:

at least a pair of acoustic sources mounted outboard from the stern of the vessel beneath the water surface, said acoustic sources being laterally spaced apart from each other, and each capable of generating a high frequency acoustic pulse of short duration;

means operable on said vessel for causing each of said sources to generate a first pulse;

at least one hydrophone housed in said streamer capable of receiving each of said first acoustic pulses from each of said sources;

means for transmitting a signal to said vessel through a separate channel in said streamer in response to

each of said first pulses received by said hydrophone;

means for monitoring said separate channel from said hydrophone during given time periods and for blocking signals transmitted through said channel during those time periods in which no signal from either of said sources is anticipated;

triggering means responsive to a transmitted hydrophone signal passing through said channel during one of said given time periods for causing either of said pair of said acoustic sources to generate a successive pulse in response to a signal from said hydrophone representing reception of an acoustic pulse from the same acoustic source; and

means for separately counting the number of times signals are emitted by said selected hydrophone to generate said successive pulses from each of said pair of acoustic sources and for separately measuring the elapsed times from the first initiated pulse to the receipt of the last selected number of hydrophone signals detected from each of said pair of acoustic sources.

2. Apparatus for use in redundantly determining the position of a marine seismic streamer towed directly behind the stern of a vessel, which comprises:

first and second acoustic sources mounted apart from each other and outboard from the stern of the vessel below the water surface, each source being capable of generating high frequency acoustic pulses of short duration;

at least one hydrophone housed in said streamer capable of receiving pulses from said acoustic sources and means for transmitting a signal to said vessel through a separate channel in said streamer in response thereto;

means for monitoring said separate channel from said at least one hydrophone in a given time period and for blocking transmitted signals through said channel during those time periods in which no pulses are anticipated from either of said first or second acoustic sources;

external means operable on said vessel for causing said first source to generate a pulse;

triggering means responsive to a transmitted signal during a first given time period for causing said first acoustic source to generate another pulse;

means for counting the number of times signals are emitted by said at least one hydrophone to generate said successive pulses and means for measuring the elapsed time from the first pulse generated by said first source to the receipt of the last of a selected number of hydrophone signals generated by said first acoustic source;

means for causing said second source to generate a pulse after said first source has completed transmitting pulses for said at least one hydrophone;

triggering means responsive to a transmitted signal during another given time period for causing said second acoustic source to generate a successive pulse; and

means for counting the number of times signals are emitted by said at least one hydrophone to generate said successive pulses and means for measuring the elapsed time from the first pulse generated by said second source to receipt of the last of a selected number of hydrophone signals generated by said second acoustic source.

3. Apparatus for use in redundantly determining the position of a seismic marine streamer towed behind the stern of a vessel, which comprises:

a first acoustic source mounted outboard from the stern of the vessel beneath the water surface which is capable of generating high frequency acoustic pulses of short duration;

a second acoustic source mounted apart from said first acoustic source and outboard from the stern of the vessel beneath the water surface which is capable of generating a high frequency acoustic pulse of short duration that is distinguishable from pulses from said first acoustic source;

means operable on said vessel for causing each of said first and second acoustic sources to generate their respective pulses;

at least one hydrophone housed in the streamer capable of receiving said pulses from said acoustic sources and means for transmitting distinguishable signals through a separate channel in the streamer to said vessel in response thereto;

means for monitoring said separate channel from said at least one hydrophone in given time periods and for blocking signals through said separate channel during those times in which no acoustic pulses are expected from either of said acoustic sources;

first triggering means for causing said first acoustic source to generate another pulse in response to receipt of a nonblocked transmitted hydrophone signal during a first given time period, said signal being emitted as a result of a pulse received from said first acoustic source;

second triggering means for causing said second acoustic source to generate another pulse in response to another transmitted hydrophone signal during a second given time period emitted as a result of a pulse received from the second acoustic source; and

means for counting the number of times signals are emitted by said at least one hydrophone to generate said other pulses after a predetermined number of signals from said hydrophone have been counted as a result of pulses generated by said first and second acoustic sources and for measuring the elapsed time from the first initiated pulse to the receipt of the last of a selected number of hydrophone signals from each of said acoustic sources.

4. Apparatus for use in redundantly determining the position of a marine streamer towed directly behind the stern of a vessel, which comprises:

(a) at least a pair of acoustic sources mounted outboard from the stern of the vessel and laterally spaced apart beneath the water surface, said sources being capable of generating high frequency sound pulses of short duration;

(b) means operable on said vessel for causing said sources independently to generate pulses;

(c) a plurality of hydrophones spaced apart along the length of said streamer capable of receiving said pulses and means for transmitting a signal to said vessel through separate channels in said streamer in response to each of the source originated pulses being received by each of said hydrophones;

(d) means for blocking signals transmitted through said channels during preselected time periods in which no signals from either of said pair of sources are anticipated;

(e) triggering means responsive to a nonblocked hydrophone signal generated by one of said sources and transmitted from the furthest hydrophone in said streamer for causing said one acoustic source to generate another pulse;

(f) means for counting the number of times signals are emitted by said furthest hydrophone in response to said one source and for stopping the generation of said other pulses by said one source after a predetermined number of said signals have been received;

(g) means for simultaneously monitoring the channels from all of said hydrophones and measuring the elapsed time from initiation of the first acoustic pulse by said one source to the receipt of each hydrophone signal in response to said one source along the length of said streamer;

(h) additional triggering means responsive to a nonblocked hydrophone signal generated by the other of said sources and transmitted from the furthest hydrophone in said streamer for causing said other acoustic source to generate another pulse;

(i) means for counting the number of times signals are emitted by said furthest hydrophone in response to said other source and for stopping the generation of said other pulses by said other source after a predetermined number of said signals have been received; and

(j) means for simultaneously monitoring the channels from all of said hydrophones and measuring the elapsed time from initiation of the first acoustic pulse by said other source to the receipt of each hydrophone signal in response to said other source along the length of said streamer.

5. Apparatus for use in determining the location of a marine streamer as recited in claims 1, 2, 3 or 4, further comprising: means to automatically limit the amplitude of the acoustic source pulses with respect to the receiving sensitivity of the hydrophone to reduce reverberation from the air-sea interface and the ocean floor and to minimize power consumption by said acoustic sources.

6. Apparatus for determining the location of a marine streamer as recited in claims 1, 2, 3 or 4, wherein the frequency of the acoustic pulses from the acoustic sources is between 3.5 and 10 kilohertz and said pulses have a duration in the range of monocycle to 20 cycles.

7. A method of redundantly determining the position of a marine streamer towed behind the stern of a vessel, which comprises:

generating first acoustic pulses of high frequency and short duration with at least two acoustic sources spaced apart beneath the water surface and outboard from the vessel stern;

said acoustic pulses being distinguishable from each other by at least one hydrophone housed in the streamer, separately detecting said acoustic pulses and in response thereto transmitting a signal along a separate channel carried by the streamer to said vessel;

blocking transmission of signals along said channel during time periods in which no acoustic pulses are anticipated;

triggering one of said acoustic sources into generating another acoustic pulse upon receipt of an unblocked signal corresponding to a pulse from said one source being received by said hydrophone;

triggering the other of said acoustic sources into generating another acoustic pulse upon receipt of an unblocked signal corresponding to a pulse from said other source being received by said hydrophone;

separately counting the number of signals emitted by said hydrophone in response to each of said acoustic pulses and stopping the generation of other pulses by each of said sources after predetermined numbers of signals have been counted from each of said sources; and

separately measuring the time lapse from the time of initiation of said first pulse to the time of receipt of the last of said predetermined numbers of hydrophone signals for each of said two acoustic sources.

8. A method of redundantly determining the position of a marine streamer towed behind the stern of a vessel which comprises:

generating a first acoustic pulse of high frequency and short duration which an acoustic source located beneath the water surface outboard from the stern of the vessel;

generating a second acoustic pulse of high frequency and short duration with another acoustic source laterally spaced apart from the first acoustic source beneath the water surface;

detecting said first and second acoustic pulses with at least one hydrophone housed in the streamer, said hydrophone responding by transmitting separate signals along a separate channel carried by the streamer to said vessel;

blocking transmission of signals along said channel during those time periods in which no acoustic pulses are anticipated from either said first or said other acoustic sources;

triggering said first acoustic source into generating another pulse upon receipt of an unblocked signal from said hydrophone corresponding to reception of said first pulse from said first acoustic source;

triggering said other acoustic source into generating a further pulse upon receipt of an unblocked signal from said hydrophone corresponding to reception of said second pulse from said other acoustic source;

separately counting the number of signals emitted by said hydrophone from said first and said other acoustic sources and stopping the generation of said other pulses after predetermined numbers of signals have been counted from each of said sources;

measuring the time lapse from the initiation of said first pulse to the receipt from said hydrophone of said predetermined number of signals emitted in response to said other pulses from said first acoustic source; and

separately measuring the time lapse from the initiation of said second pulse to the receipt from said hydrophone of said predetermined number of signals emitted in response to said further pulses from said other acoustic source.

9. A method of redundantly determining the position of a marine streamer towed behind the stern of a vessel, which comprises:

generating first acoustic pulses of high frequency and short duration with each of at least a pair of acoustic sources located beneath the water surface and laterally spaced apart from each other outboard from the vessel stern, said acoustic pulses from said pair of acoustic sources being distinguishable from each other;

detecting each of said acoustic pulses with at least one hydrophone housed in the streamer which responds by transmitting a signal corresponding to each of said pulses along a separate channel carried by the streamer to said vessel;

blocking transmission of signals along said channel during each time period in which no acoustic pulses are anticipated;

triggering each of said pair of acoustic sources into generating another acoustic pulse upon receipt of an unblocked signal corresponding to a signal from

the one of said acoustic sources generating said pulse;

separately recording a quantity representative of the average travel time of said first pulse and a plurality of said other pulses to said hydrophone in said streamer from each of said acoustic sources; and

in response to a given value of said quantity stopping the generation of said other acoustic pulses by each of said sources.

* * * * *

United States Patent [19]

Neeley

[11] **Patent Number:** 4,641,287

[45] **Date of Patent:** Feb. 3, 1987

[54] METHOD FOR LOCATING AN ON-BOTTOM SEISMIC CABLE

[75] Inventor: Walter P. Neeley, Irving, Tex.

[73] Assignee: Mobil Oil Corporation, New York, N.Y.

[21] Appl. No.: 605,089

[22] Filed: Apr. 30, 1984

[51] Int. Cl.⁴ G01V 1/38

[52] U.S. Cl. 367/19; 367/106

[58] Field of Search 367/18, 19, 20, 118, 367/130, 106

[56] References Cited

U.S. PATENT DOCUMENTS

4,375,089 2/1983 Thigpen et al. 367/20

4,446,538 5/1984 Zachariadis 367/19

Primary Examiner—Nelson Moskowitz

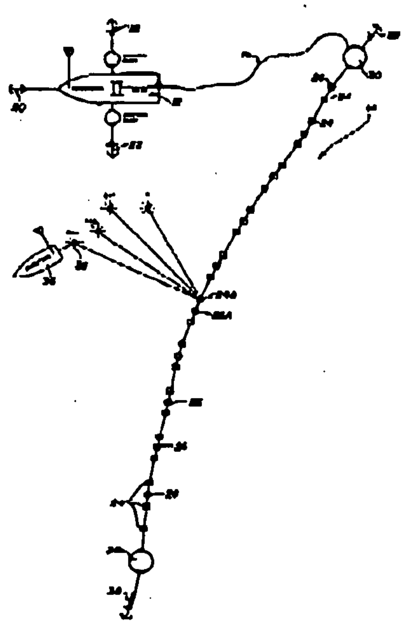
Assistant Examiner—Ian J. Lobo

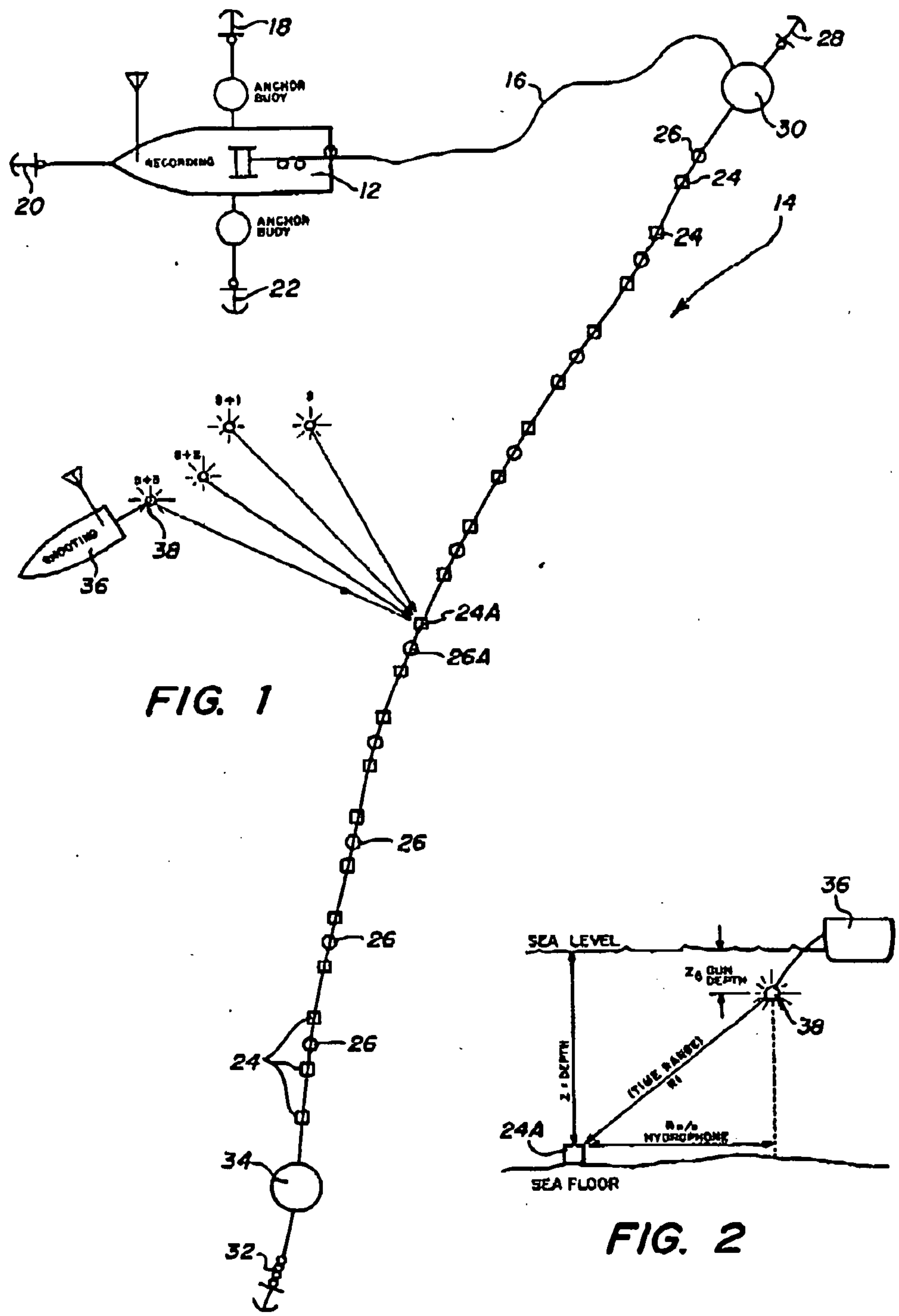
Attorney, Agent, or Firm—Alexander J. McKillop; Michael G. Gilman; Charles J. Speciale

[57] **ABSTRACT**

A method for locating an ocean bottom seismic cable is disclosed wherein a series of shots from a seismic pulse generator are fired. The distance to one seismic pulse detector is determined for each shot defining a spherical surface upon which the detector may be located. The intersection of the spherical surfaces determine the exact location of the detector. Depth detectors may be used to eliminate one half of the possible locations for each shot.

1 Claim, 2 Drawing Figures

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ANCHOR BUOY
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SEA LEVEL
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Z = DEPTH
24A
SEA FLOOR

FIG. 1

FIG. 2

METHOD FOR LOCATING AN ON-BOTTOM SEISMIC CABLE

BACKGROUND OF THE INVENTION

In present day seismic exploration there are several methods for acquiring data in a marine environment. The most common method is to use a marine vessel to tow a line of seismic acoustic pulse detectors behind a line of acoustic pulse generators. Unfortunately, this type of arrangement does not permit extremely long spacing between the line of acoustic pulse generators and acoustic pulse detectors. In a system where a line of acoustic pulse detectors are towed behind the acoustic pulse generator, reflection data is obtained. Reflection data is that data based upon returning acoustic waves that are reflected back from a subsurface interface or change in density. By extending the spacing between seismic pulse generators and seismic pulse detectors, refraction data may also be obtained. Refraction data is that data based upon acoustic waves that are returning back from the source side of an interface after traveling along the subsurface interface.

A method for acquiring marine seismic data which permits extended spacing between seismic pulse generators and seismic pulse detectors is the use of an on-bottom seismic cable. By extending the spacing between a seismic pulse source or generator and seismic pulse receivers, refraction and reflection data may be obtained.

An on-bottom seismic cable is similar to a streamer cable of seismic pulse detectors such as that towed behind a marine vessel. A streamer cable comprising a plurality of hydrophone groups spaced along its length can be used as an on-bottom cable, with the proper weight added to remove buoyancy. This assures that the streamer will sink and remain fairly stationary despite the ocean-bottom currents. More detailed information concerning the construction of an ocean bottom seismic cable can be found by referring to copending patent applications Ser. Nos. 579,042, 579,042 and 579,043, titled "Strain Member Chassis", "On Bottom Cable Termination" and "Jacketed Cable Section", respectively, all assigned to the present assignee.

Although an ocean bottom cable has a marker buoy at each end, the length of the cable is several miles and much irregular terrain lies between the buoys. As such, the cable will have a depth variance and a variance from a straight line connecting the two marker buoys. The depth of the ocean bottom cable can be indicated by depth detectors which may be spaced along the length of the cable. The actual location of the acoustic pulse detectors is unknown because the deviation from the straight line connecting the buoy locations is not determined and can be as great as several hundred meters.

SUMMARY OF THE INVENTION

The present invention discloses a method for determining the exact position of an ocean bottom seismic cable. A plurality of spaced apart shots are fired from an acoustic pulse source. A response to each of the shots is produced by an acoustic pulse detector on the ocean bottom cable. The travel time of each shot implies a distance between the source and detector. The distance may be used as a radius defining a spherical surface upon which the detector is located. The intersection of the spheres defined by successive shots define a circumference upon which the detector must be located. The intersection of a third sphere with the circumference thus defined produces two distinct possible locations of the detector. Depth detectors are used to control the possibilities and indicate the exact location of the detector.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of an ocean bottom seismic cable system.

FIG. 2 is a plan view illustrating location relationships of a portion of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, an ocean bottom cable system for acquiring seismic data is illustrated as having a recording boat 12 connected to an ocean bottom cable 14 through a floating lead-in connection 16. Recording boat 12 is anchored by anchors 18, 20 and 22 to assure that it does not drift and change the position of ocean bottom cable 14. Ocean bottom cable 14 consists of a series of acoustic pulse detectors 24 spaced apart approximately 50 m. In the preferred embodiment, ocean bottom cable 14 is designed for 120 traces, that is, it includes 120 hydrophone groups. Also included on ocean bottom cable 14 are depth detectors 26 which are spaced apart approximately 100 m. Depth detectors 26 may be of any type currently in use in the art and are used to indicate the depth below sea level of that particular portion of ocean bottom cable 14. The portion of ocean bottom cable 14 closest to recording boat 12 is anchored by anchor 28 identified by marker buoy 30. The far end of ocean bottom cable 14 is anchored by anchor 32 identified by marker buoy 34. Located alongside of ocean bottom cable 14 is shooting boat 36. Shooting boat 36 is illustrated as having fired an air gun 38 which it is towing at locations S, S+1, S+2, and S+3 to locate the exact position of ocean bottom cable 14.

For simplicity, travel of acoustic pulses from shot location S, shot location S+1, shot location S+2, and shot location S+3 will be discussed only in connection with acoustic pulse detector 24*a*. Depth detector 26*a* will provide the depth information for acoustic pulse detector 24*a*. In operation, the acoustic pulse generated at each one of the shot locations will be received by each acoustic pulse detector on ocean bottom cable 14. Using the location method of the present invention, the position of ocean bottom cable 14 will be determined at the interval of the acoustic pulse detectors.

To locate a portion of ocean bottom cable 14, air gun 38 is fired first at location S, then at location S+1, then at location S+2, and finally at location S+3. The acoustic pulse generated at each of these locations will be detected by acoustic pulse detector 24*a* which will produce a response thereto indicating the arrival of the acoustic pulse. The arrival time from each of the shot locations will be different. By correlating the travel time with velocity of acoustic pulses in water, a distance may be determined. The distance for each location defines the surface of a sphere as possible locations for acoustic pulse detector 24*a*. By plotting the sphere for two locations, location S and location S+1, two spheres may be graphed. The only possible location for acoustic pulse detector 24*a* consistent with spheres determined by the travel time from shot location S and

shot location S+1 is a circle defined by the intersection of the two spheres. By graphing a sphere based upon the travel time with its correlated distance for shot location S+2, a third sphere may be graphed. The sphere from shot location S+2 may be plotted against the sphere from shot location S+1 or the sphere from shot location S to provide an additional circle at its intersection. The intersection of the two circles generated by the intersection of two sets of intersecting spheres will produce two possible locations for acoustic pulse detector 24a provided S, S+1 and S+2 locations do not constitute a straight line. By the same token, graphing the sphere from shot location S and the sphere from shot location S+1 and the sphere from shot location S+2 will produce the same two points as possible locations for acoustic pulse detector 24a as the intersection of the two circles defined by the intersecting spheres.

Of the two possible locations for acoustic pulse detector 24a, one will be in the air and inconsistent with the depth indication of depth indicator 26a. Thus, the exact location of acoustic pulse detector 24a maybe determined by the intersection of three spheres generated from three shot locations where acoustic pulse source 38 had been fired and the data received from depth detector 26a.

Referring now to FIG. 2, a side view of the relationship between shooting vessel 36, acoustic pulse source 38 and acoustic pulse detector 24a is illustrated. When acoustic pulse source 38 is fired, acoustic pulse will travel in a straight line to acoustic pulse detector 24a in a given travel time. The distance between acoustic pulse source 38 and acoustic pulse detector 24a may be calculated by multiplying the travel time times the velocity of acoustic pulse in sea water, which is approximately 5 ft./ms. By using the travel time, a distance R_T may be calculated. A depth equal to Z for acoustic pulse detector 24a may be obtained from depth detector 26a. Gun depth, Z_G may be easily obtained from shooting vessel 36 to obtain the distance from acoustic pulse source 38 to the depth of acoustic pulse detector 24a. With this information, and the use of the Pythagorean Theorem, the horizontal distance from acoustic pulse source 38 to acoustic pulse detector 24a may be determined. For a first shot point S, the horizontal distance from acoustic pulse source 38 to acoustic pulse detector 24a may be plotted as a circle. Similarly, a circle may be plotted for a second shot point S+1 and a third shot point S+2. The intersection of these three circles give the location of acoustic pulse detector 24a projected to a horizontal plane defined by sea level.

By use of any of the foregoing methods, the location of ocean bottom cable 14 may be determined with a high degree of accuracy. Merely drawing a straight line between marker buoy 30 and tail buoy 34 does not accurately indicate the location of ocean bottom cable 14. This is due to the uneven terrain of the ocean bottom, the ocean currents and wave action when ocean bottom cable 14 is being laid. The location of ocean bottom cable 14 is essential in acquiring accurate seismic data since the depth of an interface which reflects or refracts seismic data is determined by the travel time from an acoustic pulse source, such as source 38, and acoustic pulse detector, such as detector 24a. Since acoustic pulse detectors 24 may be several hundred meters from a straight line drawn between marker buoy 30 and tail buoy 34, the depth of an interface measured by reflected data may be off by over a hundred meters. Thus, using the method of the present invention, the location of an ocean bottom cable may be determined accurately to provide a greater degree of accuracy in the acquiring of seismic data.

While the present invention has been described by way of preferred embodiment, it is to be understood as not limited thereto but only by the scope of the following claim.

I claim:

1. A method for determining the location of an ocean bottom cable having acoustic pulse detectors comprising the steps of:

firing an acoustic pulse source at a first location;

producing a first response thereto by a first acoustic pulse detector located on the said cable;

determining the distance between said first location and said first acoustic pulse detector, said distance defining a spherical surface;

firing said acoustic pulse source at a second location;

producing a second response thereto by said first acoustic pulse detector;

determining the distance between said second location and said first acoustic pulse detector, said distance defining a spherical surface;

defining a line of possible loctions of said first acoustic pulse detector by the points common to said distance between said first location and said first acoustic pulse detector and to said distance between said second location and said first acoustic pulse detector;

firing said acoustic pulse source at a third location;

producing a third response thereto by said first acoustic pulse detector;

determining the distance between said third location and said first acoustic pulse detector, said distance defining a spherical surface;

identifying two possible locations of said first acoustic pulse detector by the points common to said line of possible locations of said first acoustic pulse detector and said distance between said third location and said first acoustic pulse detector; and

eliminating one of said two possible locations as being above sea level;

providing a depth detector in close proximity to said first acoustic pulse detector;

determining the depth of said first acoustic pulse detector; and

confirming the location of said first acoustic pulse detector by eliminating locations of said line of possible locations inconsistent with said depth of said first acoustic detector.

* * * * *

Remote User

[redacted]

14.0223-GB, FURTHER EXAMINATION REPORT, 11/20/07 12:00 PM (2ND) 12/28/2005

4 pages ✓

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http://www.patent.gov.uk

Your Reference: AMS.P52304GB
Application No: GB0223673.5

28 December 2005

Dear Sirs

Patents Act 1977: Examination Report under Section 18(3)

Latest date for reply: **28 February 2006**

I have re-examined your application in response to your agent's letter of 12 December 2005 and enclose two copies of my further examination report.

By the above date you should either file amendments to meet the objections in the enclosed report or make observations on them. If you do not, the application may be refused.

Yours faithfully

Stephen Jennings
Examiner

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Your ref :	AMS.P52304GB	**Examiner :**	Stephen Jennings
Application No:	GB0223673.5	**Tel :**	01633 814986
Applicant :	WesternGeco Seismic Holdings Limited	**Date of report :**	28 December 2005
Latest date for reply:	28 February 2006	Page 1/2	

Patents Act 1977
Examination Report under Section 18(3)

Basis of the examination

1. My examination has taken account of the amendments filed with your agent's letter of 12 December 2005.

Novelty (Section 1(1)(a))

2. The invention as defined in independent claims 1 and 19 is not new because it has already been disclosed in each of the following documents:

US 4,376,301 [Roberts]
WO 84/03153 [Kongsberg Vapenfabrikk]

3. In your letter of 12 December 2005 you have submitted that neither of the above mentioned documents disclose or suggest that positioning signals are provided to the seismic sensors concurrently with seismic survey data. I have carefully considered this argument but I am not persuaded by it. It is true that neither of the documents explicitly refers to the positioning signals being provided concurrently with the survey signals, but I consider this to form part of at least the implicit teaching of each document. In the case of US 4376301 it is clear that an object of the apparatus and method defined therein is to determine the exact position of the seismic sensors (hydrophones) at the time the pressure waves (i.e. the survey signals) are detected, as mentioned at column 1 lines 28-30. In the light of this stated object of the invention, the skilled reader would understand that the disclosed method would be used in practice to determine the position of the hydrophones during the course of a seismic survey. Furthermore the skilled reader would readily appreciate that the high frequency positioning signals used in US 4376301 would enable these signals to be easily distinguished from the seismic survey signals using any suitable well known signal processing technique. Similarly I consider that the positioning signals in WO 84/03153 would, in practice, be provided to the seismic sensors concurrently with the seismic survey signals so as to determine the positions of the hydrophones at the time the seismic data is acquired. Page 8 lines 10-15 makes clear that the positioning signals are selected to be of a frequency and type 'which make them easily recognisable in the registration pictures from the hydrophones'. The skilled reader would understand this to mean that the hydrophones are concurrently recording survey data and positioning data. Accordingly, I remain of the opinion that independent claims 1 and 19 lack novelty over the cited documents.

Your ref : AMS.P52304GB
Application No : GB0223673.5

Date of report: 28 December 2005
Page 2 / 2

[Examination Report contd.]

The Dependent Claims

4. A number of the claims dependent on claims 1 and 19 also lack novelty or inventive step in the light of the two cited documents. The details of these objections are set out in my earlier examination report and I have therefore not repeated the objections here.

Clarity, Conciseness, Support and Plurality (Section 14(5))

5. In view of the above comments regarding the teaching of the two cited documents, I am of the opinion that the comments in paragraphs 16-19 of my examination report of 8 June 2005 remain valid. On amendment to address the above novelty objections you should ensure that the claims are concise, when read as a whole, and moreover that they relate to a single inventive concept.

6. You do not appear to have provided an amendment or an observation to address the objection set out in paragraph 26 of my examination report of 8 June 2005. This issue will need to be satisfactorily addressed before the application may proceed to grant.

7. The word 'sensors' in the first line on page 18 (in claim 13) should presumably read 'sensor'. You may wish to correct this typographical error.

8. Lines 12-15 state that 'in *one* embodiment' the received signals include contributions from the seismic signals and the positioning signals. This suggests that this is not the case for *all* embodiments. On amendment you should therefore ensure that the description does not refer or allude to embodiments which are outside the scope of the claims so as to ensure that no doubt is cast on the scope of your invention.

Remote User

lgoldsmith

14.0223-GB, FURTHER EXAMINATION REPORT, 11/20/07 12:01 PM (3RD) 3/30/2006

3 pages

AM-5

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http://www.patent.gov.uk

Your Reference: AMS.P52304GB
Application No: GB0223673.5

30 March 2006

Dear Sirs

Patents Act 1977: Examination Report under Section 18(3)

Latest date for reply: **30 May 2006**

I have re-examined your application in response to your agent's letter of 28 February 2006 and enclose two copies of my further examination report.

By the above date you should either file amendments to meet the objections in the enclosed report or make observations on them. If you do not, the application may be refused.

Yours faithfully

Stephen Jennings
Examiner

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Your ref :	AMS.P52304GB	**Examiner :**	Stephen Jennings
Application No:	GB0223673.5	**Tel :**	01633 814986
Applicant :	WesternGeco Seismic Holdings Limited	**Date of report :**	30 March 2006
Latest date for reply:	30 May 2006	**Page 1/1**	

Patents Act 1977
Examination Report under Section 18(3)

Basis of the examination

1. My examination has taken account of the amendments filed with your agent's letter of 28 February 2006.

Support (Section 14(5)(c))

2. The independent claims all require that a positioning signal is provided to and received at the seismic sensor, or sensors. I take this to mean that the positioning signal must be an acoustic signal. Page 7 lines 9-11 still suggests that there are embodiments of the invention which use signals other than acoustic signals. This inconsistency between the claims and the description casts doubt on the scope of the invention and must be resolved by suitable amendment of the description before this application can proceed to grant.

Remote User

LGoldsmith

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http://www.patent.gov.uk

Your Reference: AMS.P52304GB

27 June 2006

Dear Sir/Madam

PATENTS ACT 1977: PATENTS RULES 1995
NOTIFICATION OF GRANT: PATENT SERIAL NUMBER:GB2394045

1. I am pleased to tell you that your patent application number GB0223673.5 complies with the requirements of the Act and Rules, and that you are therefore granted a patent (for the purposes of Sections 1-23 of the Act) as from the date of this letter.

2. Grant of the patent is expected to be announced in the Patents and Designs Journal on 26 July 2006. In accordance with section 25(1), the patent will be treated for all later sections of the Act as having been granted and as taking effect on that date. The patent specification will be published on the same date, and you will receive the Certificate of Grant for your patent and a copy of the specification shortly afterwards.

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(7 pages)

(12) UK Patent Application (19) GB (11) 2 089 043 A

(21) Application No 8136889
(22) Date of filing 8 Dec 1981
(30) Priority data
(31) 216196
(32) 10 Dec 1980
(33) United States of America (US)
(43) Application published 16 Jun 1982
(51) INT CL³ G01S 5/18
(52) Domestic classification G1G 1G1 1G2 6 7P RA
(56) Documents cited None
(58) Field of search G1G
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(54) Determination of the Location of a Submerged Marine Seismic Streamer

(57) The determination of the location of a submerged marine streamer 20 towed behind a seismic exploration vessel is effected by means of an array of at least three transponders 10, 12, 14 secured to the ocean floor which generate distinguishable acoustic pulses upon a command signal from the ship. These signals are received by acoustic receivers 34 housed in the streamer and by the ship. The distance to each acoustic receiver may be triangulated from the data generated.

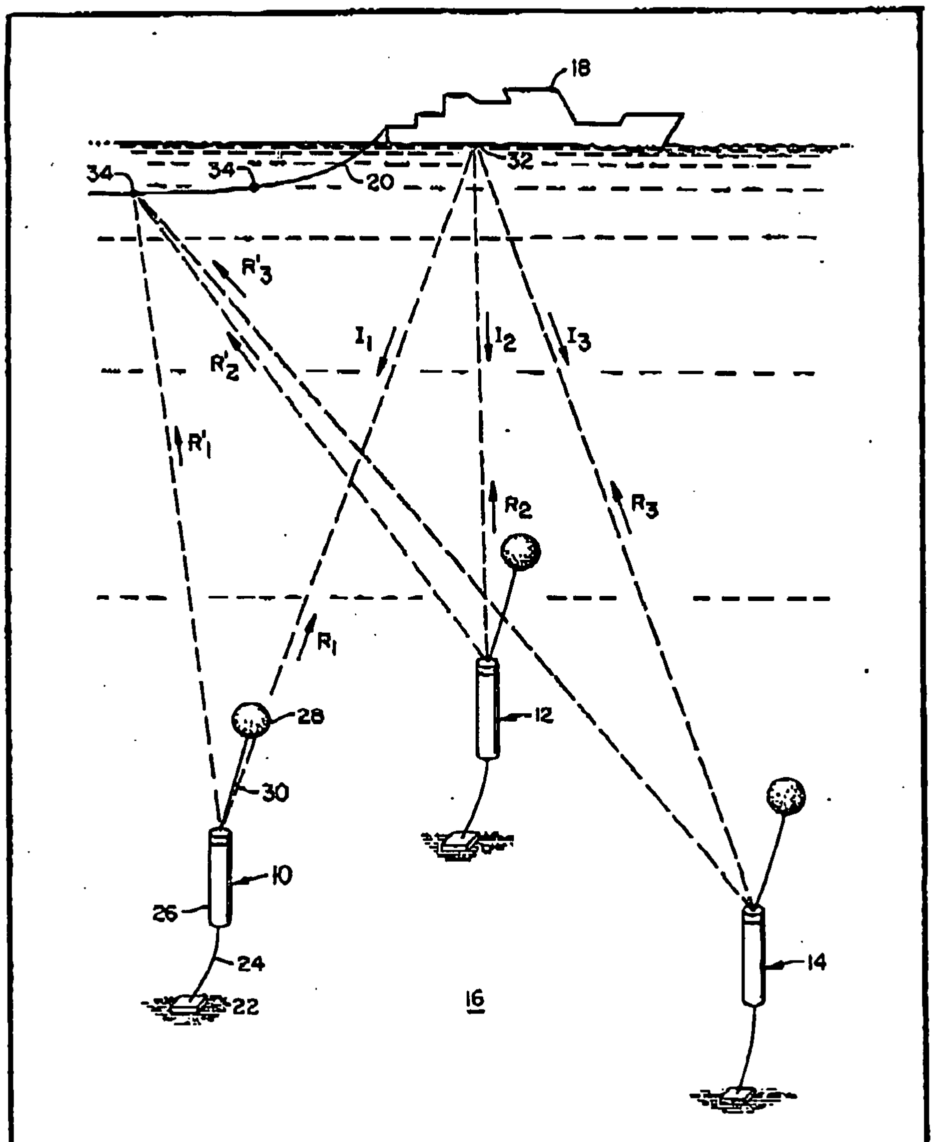

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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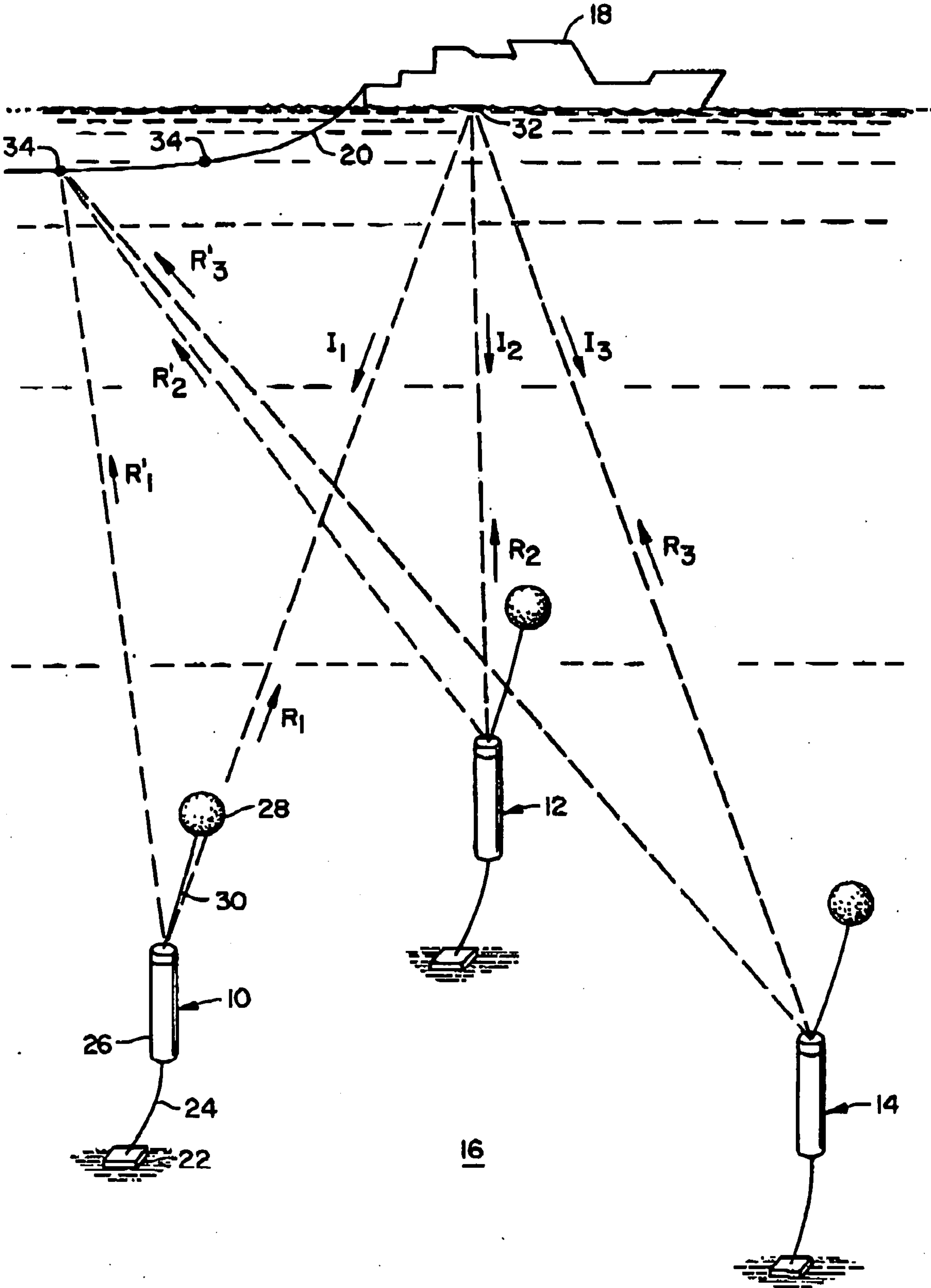

FIG.__1.

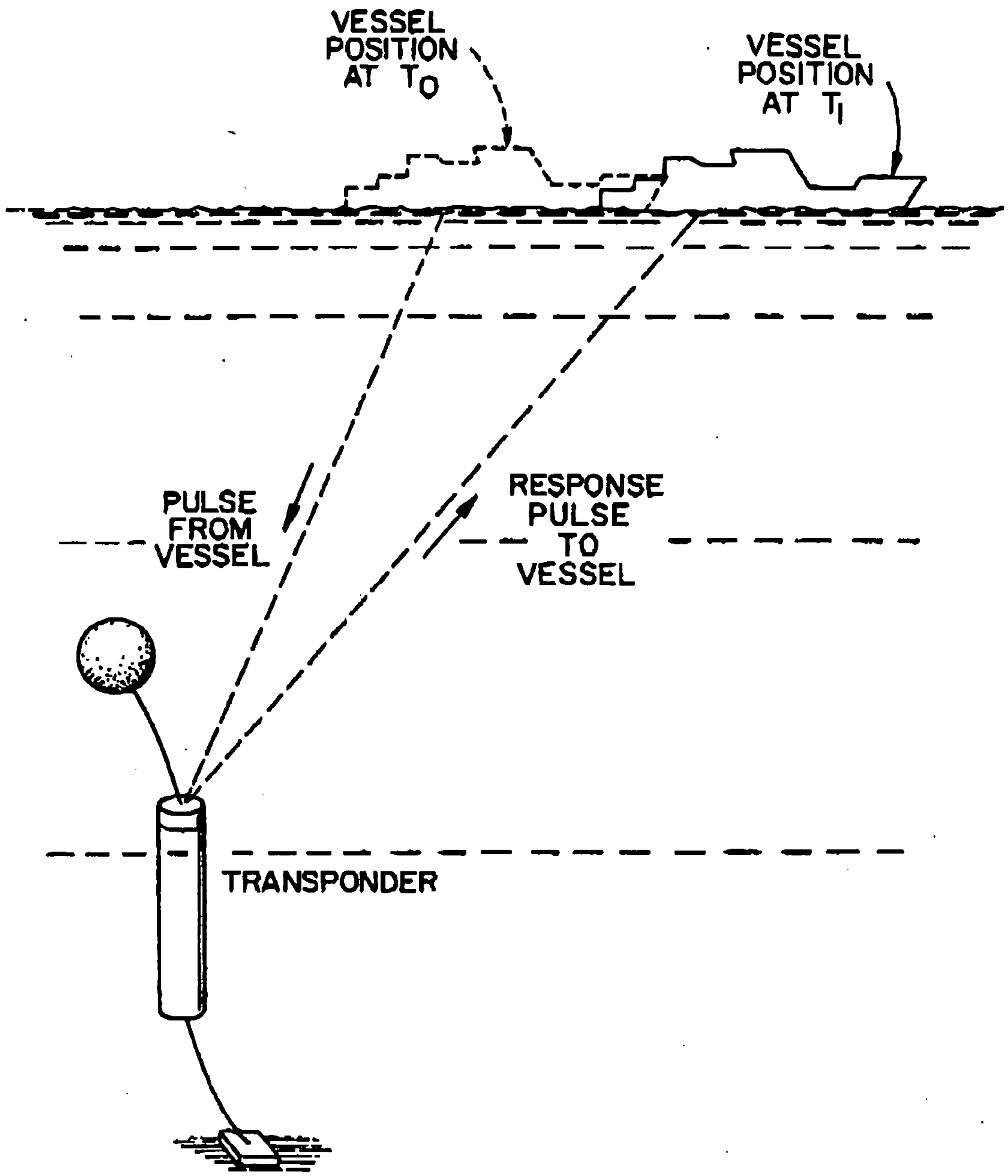
VESSEL POSITION AT T_O
VESSEL POSITION AT T_1
PULSE FROM VESSEL
RESPONSE PULSE TO VESSEL
TRANSPONDER

FIG._2.

SPECIFICATION

Apparatus and Method for the Determination of the Location of a Submerged Marine Seismic Streamer

The present invention finds principal application within the field of marine seismic exploration. More particularly, the invention is concerned with means for accurately determining the position of a towed marine seismic streamer.

In marine seismic prospecting, an exploration vessel tows a seismic streamer having a plurality of pressure sensitive detectors, commonly referred to as hydrophones. A source of seismic energy, such as an air gun or an explosive charge, is used to propagate pressure waves through the water into the underlying sea floor. Part of the energy will be reflected by subfloor geological discontinuities and subsequently detected by the hydrophones as pressure variations in the surrounding water. The mechanical energy of these pressure variations is transformed into an electrical signal by the hydrophones and transmitted through the streamer to recording apparatus aboard the vessel. The collected data may then be interpreted by those skilled in the art to reveal information about the subsea geological formations.

For the signals to be meaningful, it is necessary to know the placement of the individual hydrophones at the time the pressure waves are detected. As the vessel is continuously moving and as the streamer may extend for thousands of feet behind the vessel, accurate location of the streamer hydrophones is difficult.

Various systems have been developed to provide accurate information as to the location of the vessel.

However, it is rare for the streamer to trail directly along the path of the vessel. While the streamer is attached to the stern of the vessel, the bulk of the streamer is submerged below the water surface through the action of depth controllers along the length of the streamer. As a result, the cross-track current velocity at the streamer depth may differ from the cross-track current affecting the vessel, thereby causing the streamer to trail at an angle to the vessel's course. Other factors, which are not necessary to enumerate, may also create a variance in the path of the streamer when compared to the vessel track.

One method of estimating the location of the streamer disclosed in the prior art relies upon the addition of a tail buoy radar reflector located at the end of the streamer. On-board radar systems may then be used under optimal sea conditions to find the end of the streamer and the location of the individual hydrophones interpolated. Such systems are generally unreliable however, and render the required data suspect.

A second method taught by the art relies upon very sensitive and expensive apparatus to measure the yaw and pitch angles of the streamer end adjacent the vessel. These data, coupled with magnetic compass headings taken along the streamer and the known depth of the streamer, permit one to empirically calculate the hydrophone locations.

It is an object of this invention to provide an accurate, alternative means for locating the submerged streamer which overcomes the deficiencies of the prior art.

The present invention relates to apparatus for use in determining the location of a submerged marine streamer towed behind an exploration vessel. The system comprises: means for initiating an acoustic command signal from the vessel; at least three transponders spatially located in known positions on the sea floor so as to provide distinct acoustic paths to the vessel and streamer, each of said transponders capable of responding to the command signal from the vessel by emitting acoustic pulses of distinctly different frequencies; a plurality of spaced receivers carried by the streamer capable of receiving the different acoustic pulses emitted by the transponders and individually relaying distinct signals along the streamer to the vessel responsive to said acoustic pulses; a vessel receiver capable of receiving and distinguishing the different acoustic pulses emitted from the transponders; and means for measuring the time interval from initiation of the command signal to receipt of the signals relayed from the spaced receivers housed by the streamer and the time interval from initiation of the command signal to receipt of the pulses by the vessel receiver from the transponders.

Preferably, the transponders are placed in a non-colinear relationship and each streamer receiver is serviced by a separate channel housed in the streamer for relaying signals to the vessel. The receivers may be either active or passive, but are preferably passive to minimize weight and expense. The apparatus may further comprise means for measuring the vessel's velocity with respect to the array of transponders situated on the ocean floor. Said means for measuring the vessel's velocity may include apparatus for measuring the Doppler shift in the frequency of the pulses generated by the transponders.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:—

Fig. 1 illustrates a transponder array shown in relationship to a surface exploration vessel towing a marine streamer; and

Fig. 2 diagrammatically illustrates the effect of shipment movement on the acoustic path between vessel and transponder.

The present invention required the placement of a plurality of acoustic transponders on, or adjacent, the ocean bottom. Preferably, the transponders will be positioned on the sea floor in noncolinear arrays of at least three transponders per array. Each transponder in a given triplet is preferably placed at a sufficient distance apart to give adequate range to the ship and streamer

receivers in a given water depth. While the present invention is concerned with location of the vessel and streamer with respect to a given array and not with respect to the actual geographical location, the latter relationship may be established from knowledge of the transponder placement. Well known methods are described in the art for determination of the transponder placement and calibration and are therefore not to be considered here.

Referring to Fig. 1 of the drawings, there is shown a single array of three acoustic transponders, indicated generally by reference numerals 10, 12 and 14, positioned on the sea floor 16. An exploration vessel 18 is shown on the surface towing a streamer 20.

Transponders of the type required are commercially available and normally comprise a base plate 22, resting on the sea floor, and a cable 24 attached between the base plate 22 and the transponder body 26. A float 28 connected to the transponder body 26 by means of a cable 30 maintains the transponder body 26 at an attitude above the sea floor determined by the length of cable 24. Float 28 also provides a means of retrieval if cable 30 is severed.

Vessel 18 is equipped with an acoustic transceiver 32 for sending command or interrogation acoustic signals through the water to the transponders and, in turn, receiving responsive signals therefrom. Preferably, all transponders in the array will respond to a single frequency signal emitted by the vessel's transceiver, however, coded signals may be generated to actuate the individual transponders from the vessel, if desired.

The marine streamer 20 is submerged below the water surface by a plurality of conventional depth controllers (not shown) and will normally house hydrophones (not shown), and depth sensors (not shown) which may be interrogated from the vessel for information.

In addition, the streamer will also house a plurality of acoustic receivers 34 spaced along the length of the streamer. Receivers 34 are capable of detecting the signals generated by the transponders and relaying identifiable responses along the streamer to the vessel. Normally the streamer will have individual channels leading from each receiver to the vessel for transmitting the information. Although the receivers may be active, or powered, it is preferred that the receivers be passive.

To determine the location of receivers 34 and thus the streamer position, the vessel's acoustic transceiver 32 is triggered to send an acoustic command signal. Upon receipt of the signal, after the delay in transmission time through the water, each transponder transmits an acoustic pulse of a distinguishable frequency. These pulses are detected by transceiver 32 and by the acoustic receivers 34 housed in the streamer. For the sake of clarity, acoustic travel paths are only shown in Fig. 1 of the drawing as dashed lines for the vessel transceiver, transponders, and a single receiver in the streamer. It should be understood, however, that similar paths could be drawn for each of the receivers housed in the streamer. Arrows I_1, I_2 and I_3 represent the command pulse travelling along the dashed lines from the ship to the transponders, arrows R_1, R_2, and R_3 represent the responsive pulses from the transponders to the vessel and arrows R'_1, R'_2 and R'_3 indicate the pulse lines of travel to the receiver housed in the streamer. Since the spatial positions of the transponders on the sea floor and the speed of sound through the water are known, the receiver position may be triangulated from knowledge of the travel time for each pulse from their respective transponders.

Suitable means aboard the vessel are provided to measure the time interval between the sending of the command signal and the receipt of the pulses from the transponders and the receivers.

In Fig. 2 of the drawings, there is illustrated a single vessel moving along the water's surface at time T_0 and at a subsequent time T_1. As shown therein, the vessel's transceiver initiates a pulse at time T_0 which travels in a straight line along the indicated path to the transponder. Upon receipt of the signal at time T_d the transponder transmits a pulse which is detected by the vessel transceiver at time T_1. From the figure it may be derived that the time, T_d, is given by the formula:—

$$T_d=T_0+\frac{(T_1-T_0)}{2}(1-\frac{\vec{v}}{c})$$

wherein $\vec{v}$ is the vessel's velocity with respect to the transponder and c is the propagation speed of the acoustic pulses.

The

$$\frac{\vec{v}}{c}$$

ratio may be determined in a number of ways. A preferred method, however, relies upon the measurement of the Doppler shift in the received frequency from the transponder. Naturally, in order to determine the velocity in this manner, the transponders must be capable of generating pulses of very stable frequencies and the vessel receiver must be capable of measuring the apparent change in the frequency.

The ratio may also be calculated from the rate of change of range in the direction of the transponders and the vessel. This range rate may be determined readily from knowledge of the vessel's position and speed with respect to the transponders.

The ratio

$$\frac{\vec{v}}{c}$$

for normal ship speeds during seismic operations will usually be less than .002, since $\vec{v}$ is about 3

meters per second and c is about 1,500 meters per second. If the

$$\frac{\vec{v}}{c}$$

term is dropped then:—

$$T_d = T_0 + \frac{(T_1 - T_0)}{2}$$

with an error of less 0.2%. An error of this magnitude may be acceptable for the ocean depths encountered in oil industry for some types of seismic operations.

Knowledge of the time t_d, for the initiation of the pulses from the transponders and the measured time of pulse detection by the receivers in the streamer as transmitted to the vessel permits the calculation of the distance from each transponder to each receiver. These distances may then be triangulated to give the location of each receiver in a streamer in real time by a shipboard computer or from the recorded data in post mission analysis.

Claims

1. Apparatus for use in determining the location of a submerged marine seismic streamer as it is towed by a marine seismic exploration vessel, which comprises:—

means for initiating an acoustic command signal from the vessel;

at least three transponders adapted to be spatially located in known positions on the sea floor so as to provide distinct acoustic paths to the vessel and streamer, each of said transponders being capable of responding to the command signal from the vessel by emitting acoustic pulses of distinctly different frequencies;

a plurality of receivers adapted to be carried in spaced apart relationship by the streamer and capable of receiving the different acoustic pulses emitted by the transponders and individually relaying distinct signals along the streamer to the vessel responsive to said pulses;

a vessel receiver capable of receiving and distinguishing the different sonic pulses emitted from the transponders; and

means for measuring the time interval from initiation of the command signal to receipt of the signals relayed from the spaced receivers along the streamer and the time interval from initiation of the command signal to receipt of the pulses from the transponders by the vessel receiver.

2. Apparatus as claimed in Claim 1, wherein in use said transponders are in a non-colinear relationship.

3. Apparatus as claimed in Claim 1 or 2, wherein said plurality of receivers is passive.

4. Apparatus as claimed in Claim 1, 2 or 3, wherein each of said plurality of receivers is adapted to be serviced by a separate channel in the streamer for relaying signals to the vessel.

5. Apparatus as claimed in Claim 1, 2, 3 or 4, and further comprising;

means for measuring the vessel's velocity with respect to said transponders.

6. Apparatus as claimed in Claim 5, wherein said means for measuring the vessel's velocity includes means for measuring the Doppler shift in the frequency of the pulses generated by the transponders.

7. Apparatus for use in determining the location of a submerged marine seismic streamer as it is towed by a marine seismic exploration vessel, substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

8. A method of determining the location of a submerged marine seismic streamer towed by a marine seismic exploration vessel, which comprises:—

generating an acoustic command signal from the vessel;

receiving said acoustic command signal by a plurality of at least three transponders spatially located in known positions on the sea floor, which respond to the acoustic command signal by emitting acoustic pulses of distinctly different frequencies;

detecting the transponder acoustic response pulses with a plurality of spaced receivers carried by the streamer which relay distinct signals along the streamer to the vessel responsive to said pulses;

receiving and distinguishing the transponder acoustic pulses at the vessel; and

measuring the time interval from generation of the acoustic command signal to receipt of the signals relayed from the spaced receivers along the streamer and the time interval from generation of the command signal to receipt of the pulses at the vessel.

9. A method according to Claim 8, and further comprising:—

measuring the Doppler shift in the frequency of the pulses emitted by the transponders in order to determine the velocity of the vessel.

10. A method of determining the location of a submerged marine seismic streamer towed by a marine seismic exploration vessel, substantially as hereinbefore described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1982. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

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WO1984003153(A1).pdf
11/27/07 11:02 AM / 22pages

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WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 3 : G01V 1/38

A1

(11) International Publication Number: WO 84/ 03153

(43) International Publication Date: 16 August 1984 (16.08.84)

(21) International Application Number: PCT/NO84/00007

(22) International Filing Date: 1 February 1984 (01.02.84)

(31) Priority Application Number: 830358

(32) Priority Date: 2 February 1983 (02.02.83)

(33) Priority Country: NO

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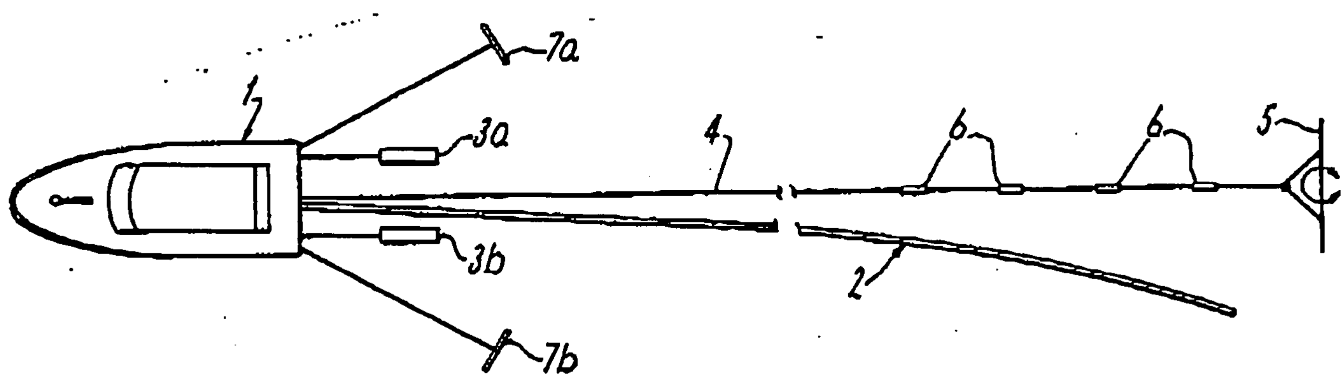
(81) Designated States: AU, BR, DE, DE (European patent), FR (European patent), GB, GB (European patent), JP, NL, NL (European patent), SU, US.

Published
With international search report.
In English translation (filed in Norwegian).

(54) Title: DEVICE IN A HYDROPHONE CABLE FOR MARINE SEISMIC SURVEYS



(57) Abstract

A device in a hydrophone cable which in connection with seismic surveys is towed through the water behind a vessel, the hydrophone cable comprising means for detecting echo signals which are reflected from the sea bed and various layers therebelow. For the purpose of improving the determination of the position of the hydrophone cable which can have a length of approx. 3000 meters, a transmission system is suggested, which comprises transmission elements arranged outside the hydrophone cable itself, the transmission elements serving to determine the position of the hydrophone cable in relation to the elements. In a simple embodiment of the device according to the invention the transmission elements are attached to or are constituted by a separate towing line (4) having a relatively small diameter, the towing line being equipped with stretching means (5) for achieving a relatively straight run. In an alternative embodiment the transmission elements can be implemented as reflectors (9a-9n) for preferably electromagnetic waves, for example in the form of light gas-filled balloons which can be attached to the hydrophone cable via thin, light lines, so that the balloons can be towed at surface positionor fairly high above the water surface. The transmission elements can also be included in a conventional radio and navigation system, possibly together with the system used by the towing vessel for its positioning, in addition to determination of distance and bearing by means of the radar system of the vessel. The transmission elements can also be

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Device in a hydrophone cable for marine seismic surveys

The present invention relates to a device in a hydrophone cable which is adapted for marine seismic surveys and is towed through the water behind a vessel, the cable comprising means for detecting echo signals from the sea bed and various layers therebelow.

Such hydrophone cables which are used in connection with seismic methods for mapping possible hydrocarbon sources below the sea bed, can be approx. 3000 meters long and be towed at a depth of approx. 10 meters. At a distance of approx. 100 meters behind the vessel there are also towed so-called air guns, the air guns firing shots according to an appropriate programme. The sound waves which are transmitted from the air guns, are reflected from the obstacles against which they may impinge below the water surface, as well as from the sea bed and various layers therebelow. The echo signals which return to the hydrophone cable, are detected by a series of hydrophones which are arranged along the cable, and which after a suitable conversion transfer the echo signals via the cable to an appropriate processing device on the towing vessel.

The seismic methods can be carried out by firing lines having a mutual distance of approx. 50 meters, and the intervals between the shots from the air guns correspond to a distance of approx. 25 meters, for thereby achieving a very fine net of squares.

Aside from comprising means for detecting echo signals from the water bottom and various layers therebelow, the hydrophone cable also comprises a plurality of compasses which indicate the form of the cable during the towing operation, and which thus constitute reference points for the line to which a sweep operation is to be referred. However, such compasses suffer from some disadvantages, the direction indication of the compasses being apt to give significant errors, since the hydrophone cable has a substantial extension.

Besides, the compass section of the cable is often significantly larger in diameter than the cable itself, and will therefore in itself be prone to generate noise. Further, the compasses necessitate a substantial number of surplus connections in the cable, which in itself is unfavourable. Further, the calibrating routine for the compasses is very sophisticated, and it is not unusual that several days are used for effecting the calibration and making all of the compass sections operable. In case magnet compasses are used, these may easily be disturbed by the magnetic fields occurring during the measuring work itself.

In connection with such known magnet compass hydrophone cables no direct visual indication of the position of the cable exists other than an end buoy which is towed freely at an arbitrary position approx. 200-300 meters behind the terminal of the hydrophone cable.

Other and more reliable and stable direction references than magnet compasses have been evaluated, for example gyro compasses, but these have not been in commercial use, since it is expected that they will constitute a means which makes the hydrophone cable more expensive.

The object of the present invention is to arrive at a device in a hydrophone cable which with simpler and less expensive means can determine the position of the hydrophone cable, the detection of the hydrophone cable's position being of importance not only during the sailing of the measuring lines itself, but also during the turning programmes after a terminated line, in connection with which significant extra distances have to be sailed before a new line is entered for thereby ensuring that the cable has a shape as straight as possible.

The object is achieved according to the invention in a device which is characterized in that it comprises a transmission system which is adapted to determine the position of the hydrophone cable, and which comprises transmission elements provided outside the hydrophone cable itself.

By using such a transmission system it is possible to achieve a less expensive and more direct measuring method, a fact which includes significantly reduced equipment expenses, especially compared to the type of compass sections used today. In a transmission system in which the transmission elements are provided outside the hydrophone cable itself, it is also possible to achieve a substantially greater operational safety. By means of the transmission system it is, aside from achieving better information about the position and shape of the hydrophone cable at any time, also possible to include the position signals in the manoeuvring operations of the vessel during the turning operation. Finally, the suggested transmission system can be made to co-operate with means serving to aligne the shape of the cable both during the line sweeping and the turning operations.

The transmission elements which are included in the proposed transmission system can either be stationarily anchored, or they may be provided on bodies floating more or less freely in the water. In the latter case the bodies carrying the transmission elements can then be connected to a continuous connection means facilitating the collection of the bodies after a measuring period.

Possibly, the transmission elements serving to transfer the position signals to or from the hydrophone cable can be provided on one or more bodies which are towed behind the vessel, the bodies being towed separately or in groups, and the bodies substantially being arranged along a straight line.

In an alternative embodiment the bodies carrying the transmission elements can be affixed to or be constituted by a separate towing line having a relatively small diameter, the towing line being provided with stretching means for achieving an approximately straight run.

The towing line with the transmission element carrying bodies can then extend at least along the overall length of the hydrophone cable.

It is to be understood that the towing line itself can be adapted for transmission of substantially longitudinal acoustic waves which are received by the hydrophone cable.

It is also to be understood that the transmission elements can comprise means for receiving position signals which are transmitted from signal elements in the hydrophone cable.

It is further to be understood that the transmission of position pulses can take place to or from the vessel, for example via radio or radar, and it is thereby achieved an electromagnetic positioning system which works independently of the seismic hydrophone system. The transmission elements indicating the position of the cable can for example be constituted by for example reflectors which are attached to the towing line, or with a suitable spacing are attached to the hydrophone cable and glide thereabove in or close to the surface by means of appropriate buoyancy means.

The position of the reflectors can then be determined by means of antennas mounted for example on the vessel itself or on paravans towed at a distance from the vessel.

Possibly the position of the reflectors can be determined by a system gliding above the hydrophone cable, for example wire controlled from the vessel.

The above described embodiments for determining the position of the hydrophone cable can in a simple manner be adapted to an adaptive regulating system for manoeuvring both the vessel and the hydrophone cable for thereby achieving a most favourable overall position at any time for covering the measuring area and complete measuring accuracy.

The signals from the transmission system can suitably be used for influencing the manoeuvring of the vessel and/or influencing a means on the vessel which can move relative thereto, or influencing means which are provided along the hydrophone cable and in this way aligne the position of the cable relative to the vessel.

If the means influencing the hydrophone cable are to constitute an as little a noise source as possible for the

hydrophone system, these means may appropriately be influenced during time intervals in which the hydrophone cable is close to inactive as regards the detection of echo signals.

The invention will in the following be further described, reference being had to the drawing, which in diagrammatical form illustrates various embodiments of the present invention.

Figure 1 illustrates diagrammatically a plurality of embodiments of the device according to the present invention.

Figure 2 is similarly a sketch illustrating further embodiments of the device according to the present invention.

Figure 3 illustrates diagrammatically further embodiments of the device according to the present invention.

Figure 4 is a sketch illustrating further embodiments of the present invention.

Figure 5 is a sketch illustrating how the hydrophone cable can be influenced in co-operation with the present device.

Referring to Figure 1, a vessel which is designated by 1, moves along the surface of a larger body of water for surveying the bottom of the body of water and areas therebelow, the vessel 1 towing a hydrophone cable 2 which can have an overall extension of for example 3000 meters. The towing of the cable 2 takes place preferably at a depth of 10 meters, and an even depth is sought maintained by means of for example active fins controlling the height direction of the cable, the specific weight of the cable being adjustable on the one hand by means of the paraffin type which is used for filling the cable, and on the other hand by ballast, for example in the form of lead plates arranged therearound.

After the vessel there are also towed a couple of air guns 3a, 3b, said guns being adapted for firing in accordance with a predetermined programme for the transmission of sound waves, which are scattered towards the sea bed and are reflected therefrom and from various geological layers therebelow. The reflected sound waves or echo signals are received by the hydrophones which are mounted in the hydrophone cable

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2, and the signals from the hydrophones are passed through the hydrophone cable to a combined storage and computing machine on the vessel for further processing to appropriate values giving a picture of the sea bed and the formations thereof.

In order to achieve an as accurate result as possible it is of greates importance to know where the various hydrophone positions of the hydrophone cables 2 are relative to the vessel and the air gun groups 3a, 3b which are found for example approx. 100 meters after the vessel 1. This accuracy is especially of great importance in the cases wherein the lines over which the hydrophone cable 2 is to be passed, are arranged as close as 50 meters, and wherein the air guns are fired at 25 meters intervals while undertaking a so-called three-dimensional seismic survey.

In Figure 1 there is as a first embodiment of a transmission system for supervising the position of the hydrophone cable 2 depicted a relatively thin steel wire 4 which preferably has a somewhat longer extension than the hydrophone cable 2 itself. Appropriately, the steel wire 4 can be equipped with a braking plate 5 or a suitable form of a controlled braking device serving to keep the wire in an as straight as possible shape during the towing operation.

In a first utilization of the thin steel wire 4 this may constitute a carrier means for substantially longitudinal mechanical sound waves which are generated at the attachment points at the vessel 1, the acoustic waves or pulses which follow the wire 4 being registered by the hydrophones in the hydrophone cable 2, since the distance between the wire and the hydrophone cable in the utmost case usually runs to approx. 100 meters.

Possibly the braking device or the plate 5 at the free end of the wire 4 can be controlled in such a way that it not necessarily finds itself in an extension of the centre line of the ship, but can be swung out in the proximity of the microphone cable, so that the signal communication between

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the wire 4 and the hydrophone cable 2 is amplified. Since the wire 4 is relatively thin and is kept under tension, the drift of the wire can be made very small, but it should in connection with the use of acoustic transmission signals be towed in a position below the water surface, so that signal communication with the microphone cable is made as favourable as possible, while at the same time reducing wave noise. The distance between the wire 4 and the cable 2 should be adjusted so that no interference occurs between the means being included in the present transmission system and the hydrophone cable.

As an alternative to the transmission of mechanical pulses along the wire 4 there might thereon be mounted small signal generators 6 which preferably can be initiated from the vessel, for example in those periods wherein the echo sound waves from the bottom are on a relatively inactive level, so that the distance between the signal generators 6 on the wire 4 and the corresponding hydrophones on the hydrophone cable 2 can be detected.

It is to be understood that the acoustic signal generators can also be arranged in the hydrophone cable at the same time as signals therefrom are registered in suitable receivers in elements provided on the wire 4. However, it might be appropriate to utilize existing hydrophone groups in the hydrophone cable 2, a fact which includes an advantage in connection with signal sources in systems outside the hydrophone cable 2.

Still another embodiment of the device comprising a transmission system which is adapted for determining the position of the hydrophone cable and which comprises transmission elements provided outside the hydrophone cable 2 itself, is illustrated in Figure 1 and takes the form of transponders 7a, 7b, which are towed on paravans located approx. 200-300 meters behind the ship and defining an angle of approx. 45°. The signals from the transponders 7a, 7b will at suitable intervals be picked up by the hydrophones

in the hydrophone cable 2 and the relative strength and the shape of the signals received by the hydrophone cable 2, will give a picture of the shape and the position of the cable relative to the towing vessel 1. The length of the paravan lines must here be adjusted so as to achieve a best possible signal/noise ratio, since longer paravan lines can give a shorter signal path to the hydrophones in the hydrophone cable, but bring the sources of noise closer thereto.

It is to be understood that the above discussed embodiments of a transmission system in which the transmission elements are provided outside the hydrophone cable itself, is to be operated with signal frequencies and types thereof which make them easily recognizable in the registration pictures from the hydrophones.

In Figure 2 there is illustrated an alternative embodiment of a device according to the present invention. As previously, 1 designates a vessel which behind itself tows a hydrophone cable 2. The signal communication to the hydrophone cable 2 is here suggested implemented by means of freely floating buoys 8a-8n, which aside from being equipped with hydro-acoustic transponders, are also equipped with radar reflectors. The buoys are dropped from the vessel when this passes the area to be investigated, and the buoys will of course drift off by stream, wind and waves, but they will not give rise to noise. The transponders in the floating buoys can be adapted for transmission of hydroacoustic signals during given periods of times, preferably during period of times in which the registration of the echo signals is not critical.

If buoys are dropped at a distance of approx. 500 meters, a number of twenty buoys could cover a sailing line of approx. 10 km in a seismic surveying net.

The buoys can preferably be connected by means of a rope 8' which appropriately can slide through an eye in the stem of the bouy until the hydrophone cable has passed by. Thereafter the buoys can be collected in a group and be hauled

in during the turning operation for another seismic line. In this period of turning the signal means in the buoys can possibly be reenergized if required.

It is to be understood that a corresponding system can comprise transponders which instead of floating on the surface of the water are dropped to the sea bed to known bottom positions for therefrom transmitting signals to the hydrophone cable. After use the transponders can be collected by means of a line and be brought to the towing vessel.

Still another variant of the transmission system according to the present invention is illustrated in Figure 3, in which reflectors for example in the form of light gass-filled balloons 9a-9n are attached to the hydrophone cable 2 which also in this case is towed behind a vessel 1. The balloons 9a-9n are attached to the hydrophone cable 2 by means of thin, light lines, so that the balloons can be towed at surface positions or at a fair height above the water surface, if required.

Such a system including floating or gliding balloons can be made very economically and can be contemplated used as a supplemental system to another transmission and measuring system. By means of the radar equipment on the vessel the position of the various balloon reflectors can be detected, and the detected echo signals from the reflectors will form a picture of the shape and position of the cable behind the towing vessel 1.

For further improving the detection of the floating reflectors radar antennas 10a, 10b can be arranged on towed paravans, as this appears from Figure 4. As previously, 9a-9n designate the floating reflecting elements which glide above the hydrophone cable 2, which on the other hand is towed by the vessel 1.

Possibly, the radar antenna can be arranged gliding in the air above the vessel 1, as this appears from Figure 3, the radar antenna here being attached to a gliding drone 11 which is located at a suitable distance and height behind

the vessel 1 towing the hydrophone cable 2. The drone 11 can suitably be controlled from the vessel 1. Further, it is to be understood that the reflector elements can co-operate with means forming a basis line established outside the vessel for thereby avoiding the uncertainty in the angular determination from a vessel in moving sea.

The determination of the position of the buoys or reflectors can also be carried out by means of for example conventional radio and navigation systems, possibly by the system used by the ship itself for the positioning thereof. These systems can be used in addition to the distance and angular determination of the buoys by means of the radar system of the ship.

On the basis of the information obtained by the above discussed embodiments as regards the position and shape of the hydrophone cable it is possible by suitable means to let the hydrophone cable be included in an adaptive control system which manoeuvres the cable in such a way that this will be positioned as favourably as possible in relation to the reference line from which data is wanted in the sailing programme.

Via mathematical modelling of the hydrophone cable the vessel can be steered automatically in relation thereto, since this steering is also based on an adaptive control system. Such systems render dynamic compensation for wind, current and sea, as well as for the influences to which the vessel and the hydrophone cable ohterwise are subjected. Contrary to steering the vessel substantially along straight heading lines it is possible by co-operating the shape of the hydrophone cable and the heading of the vessel to obtain a most favourable shape and position of the hydrophone cable relative to the desired surveying line in the sailing programme.

When a survey line has been shot the vessel must be turned so that the hydrophone cable can enter another surveying line. This turning process is very time consuming, since

the turning must be carried out in such a way that the cable must be sufficiently straight before starting a new line. By means of mathematical modelling and adaptive regulation technique based on the signals provided by means of the above discussed transmission system, such a turning programme can be put in as a completely controlled programme. In other words, the vessel can then be steered along a track which is as short as possible and renders an optimum shape of the cable prior to the commencement of another line. It is to be understood that the changing from one line to another not necessarily relates to two adjacent lines but lines which are located in various parts of the area in which the seismic surveys are to be carried out.

In Figure 5 there are diagrammatically illustrated embodiments wherein the vessel 1 towing the hydrophone cable 2 therebeind, is equipped with a suspension 12 which is adapted to influence the cable 2 for thereby either cancelling or resisting the deflections which at any time can occur during the towing operation. Possibly, the hydrophone cable 2 can be equipped with actuators, for example in the form of a steerable end rudder 13 or steerable fins provided in the longitudinal direction of the cable.

However, the use of steerable fins can pave the way for undesired acoustic noise, since in connection with seismic reflections one operates with signal levels in the magnitude range of ± 5 microbar.

However, the steering fins or the actuators can be inserted in such a way that they are active during given time intervals between the shots from the air guns, in which the accuracy, as regards the measuring technique, is of less importance. In other words, the control of the fins or the actuators will be excluded in the periods in which the feeble reflexes from the deep formations below the seabed are received, since during these periods of time a strongest possible reduction of all possible sources of noise is desired for the achievement of a most favourable signal/noise ratio.

If the cable prior to the commencement of a line sailing is sufficiently aligned, short intervals of influence of some seconds' duration can be sufficient for the cable to maintain an approximately straight shape. The fins or actuators should then be kept in a neutral noise-reduced position during the periods in which the seismic signals from the air guns are received.

As regards the rudder device 13 illustrated in Figure 5, such a towed steering device which either is located at or below the surface of the water, can be at a substantial distance from the hydrophone cable 2 for thereby constituting a noise source with minimum influence. The controlled rudder device 13 can suitably be equipped with a transmission element for determining the free end point of the cable in relation to a reference point on the vessel. Possibly, the controlled rudder device can comprise or constitute stretching means for the towing line.

It is to be understood that the above discussed transmission elements can be adapted for side detection, i.e. detection of the side at which the elements are, in relation to the hydrophone cable. Further, the system can be adapted so as to detect whether certain reference elements are approaching or moving towards and apart from each other, respectively.

Patent Claims

1. Device in a hydrophone cable (2) which is adapted for marine seismic surveys and is towed through the water behind a vessel (1) and comprises means for detecting echo signals which are reflected from the sea bottom and various layers therebelow, characterized in that the device comprises one or more supporting bodies which are provided outside or at a distinct distance from the hydrophone cable itself and from the sea bed, and that the supporting bodies comprise transmission elements which are included in a reference system for determining the position of the hydrophone cable.

2. Device as claimed in claim 1, characterized in that the transmission elements which are included in the reference system and which serve to transfer positioning signals to or from the hydrophone cable (2), are arranged stationary ashore.

3. Device as claimed in claim 1, characterized by transmission elements arranged on supporting bodies (8a-8n) floating approximately freely in the water.

4. Device as claimed in claim 1 or 3, characterized in that the bodies (8a-8n) supporting the transmission elements are connected to a continuous connection means (8') which facilitates the gathering of the bodies (8a-8n) after a measuring period, and which aids in aligning the transmission elements towards a straight line.

5. Device as claimed in claim 1, characterized in that the transmission elements are arranged on one or more bodies (6) which are towed behind the vessel (1), the bodies (6) being towed separately or in groups arranged substantially on a straight line.

6. Device as claimed in claim 1 or 5, characterized in that the bodies supporting the transmission elements are attached to or are constituted by a separate towing line (4) having a relatively small diameter, the towing line (4) being equipped with possibly controllable stretching means (5) for achieving an approximately straight run.

7. Device as claimed in claim 5 or 6, characterized in that the towing line (4) with the transmission element supporting bodies (6) extend along at least the overall length of the hydrophone cable (2).

8. Device as claimed in claim 7, characterized in that the towing line (4) itself is adapted for transmitting longitudinal acoustic waves which are picked up by the hydrophone cable (2).

9. Device as claimed in any of the claims 5-7, characterized in that the transmission elements comprise means for receiving positioning signals transmitted from signalling elements in the hydrophone cable.

10. Device as claimed in any of the claims 1-7 or 9, characterized in that the transmission elements are adapted for co-operating with radio and navigation systems or the system which the ship itself utilizes for the positioning thereof, possibly in addition to distance and direction determination by means of the radar of the ship.

11. Device as claimed in any of the claims 5-7 or 10, characterized in that the line formation of the transmission elements is determined by position detection of a point, for example an end point, in relation to the position of the vessel or with reference to a navigation

system, the line (4) which connects the transmission elements, possibly comprising controlled manoeuvring means (5) serving to bring the line (4) in a favourable position relative to the hydrophone cable (2).

12. Device as claimed in claim 1 or 5, c h a r a c t e r i z e d i n that the transmission elements are supported by or are constituted by floating or gliding supporting bodies or reflectors, for example gass-filled reflector elements (9a-9n) which are attached to the hydrophone cable (2) and are towed thereby at or above the water surface.

13. Device as claimed in claim 10 or 12, c h a r a c t e r i z e d i n that the reflector elements (9a-9n) co-operate with antennas (10a-10b) which are located in the proximity of the vessel (1), for example on paravans which are towed at a distance from the vessel or mounted stationarily relative to the vessel.

14. Device as claimed in claim 12 or 13, c h a r a c t e r i z e d i n that the reflector elements (9a-9n) are adapted to co-operate with a detection system (11) gliding above the hydrophone cable (2) and for example being controlled from the vessel (1).

15. Device as claimed in any of the claims 1-14, c h a r a c t e r i z e d i n that the transmission elements are adapted for co-operating with an adaptive regulation system for manoeuvring the vessel and/or the hydrophone cable.

16. Device as claimed in claim 15, c h a r a c t e r i z e d i n that the hydrophone cable (2) comprises actuator means (12) for optimum manoeuvring of the cable (2) in relation to the vessel (1), the actuator means (12) being arranged

on the vessel for influencing the hydrophone cable at its attachment point to the vessel.

17. Device as claimed in claim 16, characterized in that the hydrophone cable comprises means for controlled movement of the hydrophone cable in relation to the vessel, the control means being actuated substantially in intervals in which the hydrophone cable receives echo signals which are not critical.

18. Device as claimed in claim 15, characterized in that the hydrophone cable (2) is equipped with a controllable means (13) at its free towing end, the controllable means (13) possibly comprising a transmission element for position settlement of the end point of the hydrophone cable and possibly also at the same time comprising or constituting stretching means for towing lines.

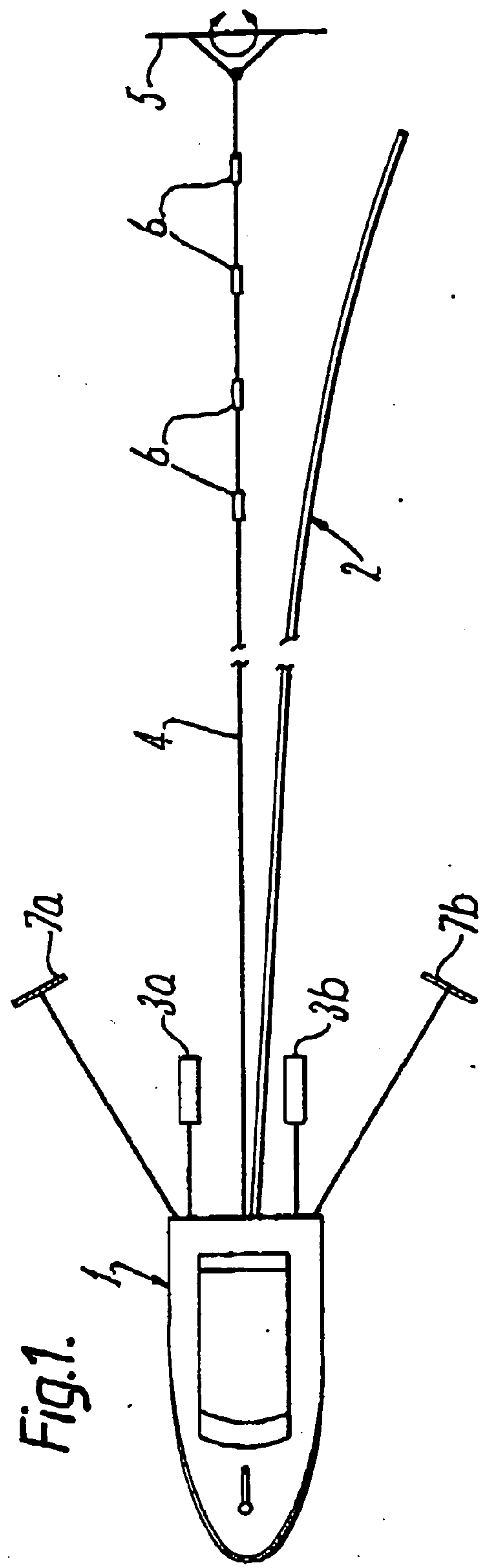

Fig.1.

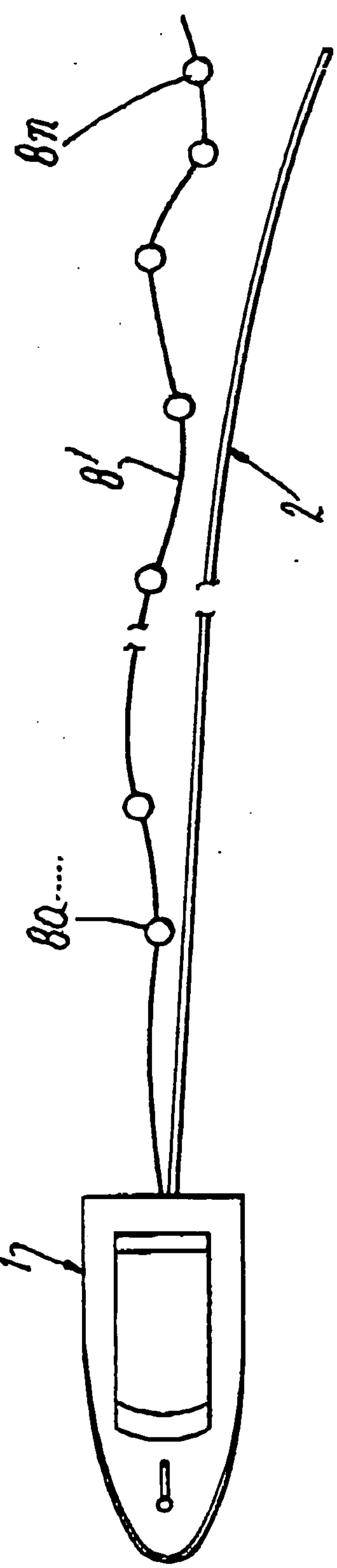

Fig.2.

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Fig.3.

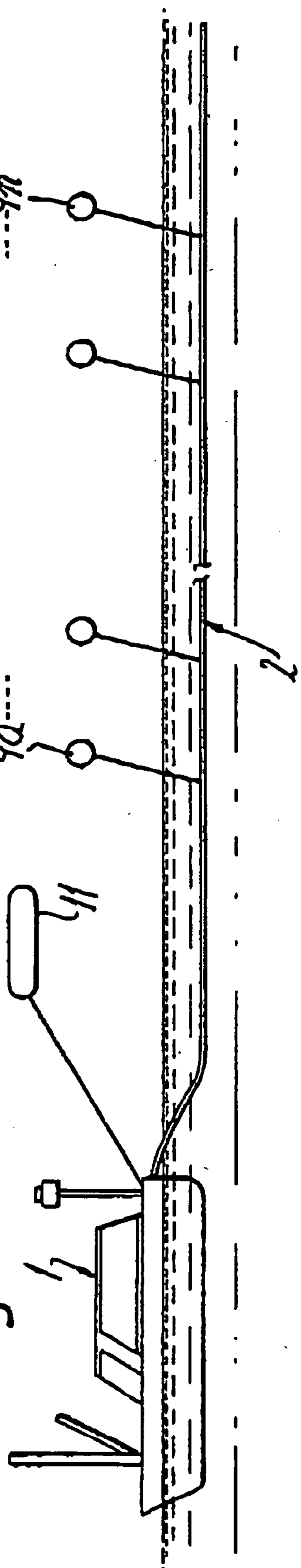


Fig.4.

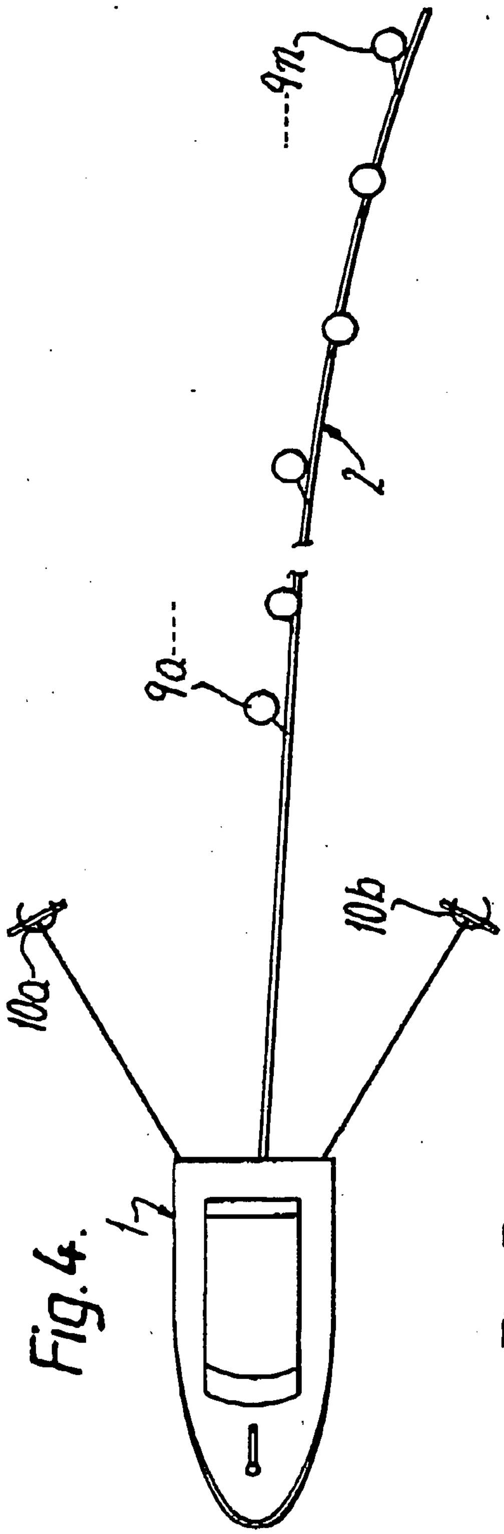
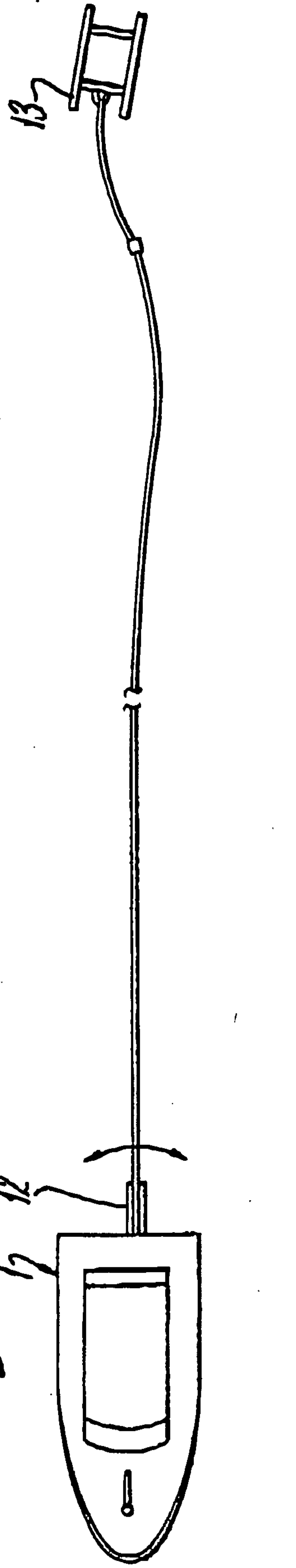


Fig.5.



INTERNATIONAL SEARCH REPORT

International Application No PCT/NO84/00007

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [8]

According to International Patent Classification (IPC) or to both National Classification and IPC 3

G 01 V 1/38

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC 3	G 01 V 1/38
National Cl	42c: 42
US Cl	181: 110; 340: 3T, 7; 367: 19

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [6]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	NO, B, 147 618 (INSTITUT FRANCAIS DU PETROLE) 31 January 1983	1
A	SE, B, 410 126 (TEXACO DEVELOPMENT CORPORATION) 24 September 1979	1

* Special categories of cited documents: [15]

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"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [9]
1984-04-09	1984-04-16
International Searching Authority [1]	**Signature of Authorized Officer [10]**
Swedish Patent Office	Ingemar Josefsson

K.L.

Remote User

lgoldsmith

FR2772931(A1).pdf
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13 pages

(19) RÉPUBLIQUE FRANÇAISE

INSTITUT NATIONAL
DE LA PROPRIÉTÉ INDUSTRIELLE

PARIS

(11) N° de publication : **2 772 931**
(à n'utiliser que pour les commandes de reproduction)

(21) N° d'enregistrement national : **97 16497**

(51) Int Cl[6] : G 01 V 1/38

(12) DEMANDE DE BREVET D'INVENTION A1

(22) Date de dépôt : 24.12.97.

(30) Priorité :

(43) Date de mise à la disposition du public de la demande : 25.06.99 Bulletin 99/25.

(56) Liste des documents cités dans le rapport de recherche préliminaire : *Se reporter à la fin du présent fascicule*

(60) Références à d'autres documents nationaux apparentés :

(71) Demandeur(s) : *CIE GENERALE DE GEOPHYSIQUE* — FR.

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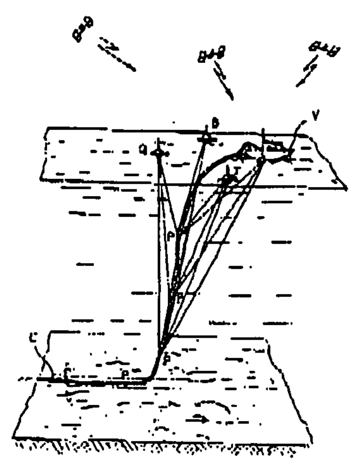
(54) SYSTEME POUR LE SUIVI DE LA MISE EN PLACE D'UN CABLE SISMIQUE SUR UN FOND MARIN A PARTIR D'UN BATEAU.

(57) Système pour le suivi de la mise en place d'un câble sismique sur un fond marin à partir d'un bateau, comportant une pluralité d'émetteurs acoustiques qui sont répartis sur le câble et qui émettent chacun un signal acoustique identifiable, caractérisé en ce qu'il comporte un réseau flottant d'au moins trois unités de réception acoustique, des moyens pour connaître la position desdites unités de réception par rapport au bateau, ainsi que des moyens pour transmettre à une unité de traitement des temps correspondant à la réception lesdites unités de réception des signaux acoustiques émis par les émetteurs portés par le câble, l'unité de traitement comportant des moyens pour calculer, à partir de ces temps et des positions desdites unités de réception, la position desdits émetteurs et donc la trajectoire du câble au fur et à mesure que celui-ci est déroulé à partir du bateau.



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La présente invention est relative aux techniques de mise en place de câbles sismiques sur les fonds marins.

Plus particulièrement, un but de l'invention est de proposer une technique permettant de positionner des câbles sismiques en eaux profondes, par exemple avec une précision inférieure à 10 mètres sous 1000 mètres de profondeur.

On connaît déjà des dispositifs permettant de connaître avec précision la position de câbles sismiques sur des fonds marins en eaux peu profondes, c'est à dire d'une profondeur de l'ordre de 100 m ou inférieure ("shallow water" selon la terminologie Anglo-saxonne généralement utilisée).

Notamment, il a déjà été proposé d'équiper les câbles sismiques de transpondeurs qui sont interrogés à partir d'un bateau source et qui émettent, lorsqu'ils sont interrogés un signal qui est reçu par des moyens de réception auxiliaires. Ces moyens de réception sont déplacés à la surface de l'eau et des moyens de calcul déterminent, en temps différé, la position des transpondeurs et donc du câble, à partir du signal reçu par lesdits moyens de réception en trois positions différentes de ceux-ci.

Une telle technique ne peut être utilisée en eaux profondes. Notamment, pour des questions de coûts, il n'est alors pas envisageable de redéployer un câble lorsque l'on s'aperçoit qu'il n'est pas convenablement positionné.

L'invention propose quant à elle une technique qui permet le suivi en temps réel de la mise en place d'un câble sismique sur un fond marin en eau profonde.

La solution selon l'invention consiste en l'utilisation d'un système pour le suivi de la mise en place d'un câble sismique sur un fond marin à partir d'un bateau, comportant une pluralité d'émetteurs acoustiques

qui sont répartis sur le câble et qui émettent chacun un signal acoustique identifiable, caractérisé en ce qu'il comporte un réseau flottant d'au moins trois unités de réception acoustique, le bateau étant avantageusement l'une de ces unités, des moyens pour connaître la position desdites unités de réception par rapport au bateau, ainsi que des moyens pour transmettre à une unité de traitement des temps correspondant à la réception par lesdites unités de réception, des signaux acoustiques émis par les émetteurs portés par le câble, l'unité de traitement comportant des moyens pour calculer, à partir de ces temps et des positions desdites unités de réception, la position desdits émetteurs et donc la trajectoire du câble au fur et à mesure que celui-ci est déroulé à partir du bateau.

Ce système est avantageusement complété par les différentes caractéristiques suivantes prises seules ou selon toutes leurs combinaisons techniquement possibles :

- les émetteurs acoustiques sont des transpondeurs qui émettent un signal acoustique à réception d'un signal acoustique d'interrogation et la position desdits transpondeurs est déterminée en fonction des temps entre l'émission des signaux d'interrogation et la réception à la surface de l'eau des signaux de réponse des transpondeurs ;
- des moyens de transmission entre l'unité de traitement et les unités de réception comportent des moyens de communication hertzienne ;
- les moyens de transmission sont bidirectionnels et en ce que simultanément à la commande de l'émission d'un signal d'interrogation par l'unité de traitement, ladite unité transmet aux différentes unités de réception un signal de synchronisation qui déclenche des compteurs destinés à permettre la mesure des temps auxquels les différents signaux de réponse des transpondeurs sont reçus ;

- des moyens pour connaître la position desdites unités de réception par rapport au bateau comportent des moyens de localisation radiosatellitaire ;
- lesdits moyens de localisation radiosatellitaire mettent en oeuvre une localisation de type cinématique relative ;
- les unités de réception sont au nombre de quatre ou cinq ; il peut bien entendu être supérieur si l'on souhaite un taux de redondance plus important ;
- le système comporte des moyens pour modifier l'écartométrie entre les unités de réception, de façon à optimiser leurs positions relatives ;
- le câble comporte en outre des capteurs de pression disposés à proximité des émetteurs acoustiques et permettant une estimation de la profondeur à laquelle lesdits émetteurs se trouvent ;
- l'unité de traitement calcule en fonction de cette position une prédiction sur les points d'impact du câble sur le fond marin, ainsi que les corrections à apporter à la trajectoire du navire pour optimiser la descente du câble.

D'autres caractéristiques et avantages de l'invention ressortiront de la description qui suit. Cette description est purement illustrative et non limitative. Elle doit être mise en regard de la figure unique annexée sur laquelle on a représenté schématiquement un exemple de mise en oeuvre possible de l'invention.

Le système qui est illustré sur la figure comporte un bateau maître, référencé par V, à partir duquel un câble sismique C, initialement monté sur un cabestan, est déroulé pour être déployé sur le fond marin. La longueur du câble sismique C est par exemple de plusieurs kilomètres.

Ce câble sismique C comporte, outre des capteurs et/ou des sources d'émission sismique, une pluralité de

transpondeurs acoustiques P (appelés "pinger" selon la terminologie anglo-saxonne couramment employée par l'Homme du Métier) qui sont répartis sur toute sa longueur. La distance qui sépare deux transpondeurs P successifs dans la longueur du câble est par exemple de 300 m.

Ces transpondeurs P sont destinés à être interrogés par un signal acoustique d'une fréquence donnée émis par des moyens d'émission acoustique que porte le bateau maître V.

A la réception de ce signal d'interrogation, les transpondeurs émettent eux-mêmes un signal acoustique d'une autre fréquence, qui est destiné à être détecté par une pluralité d'unités de réception réparties à la surface de l'eau. Ces unités de réception sont au nombre d'au moins trois et sont de préférence au nombre de quatre ou cinq, ce qui permet de disposer d'informations redondantes et donc de mettre en oeuvre un traitement de contrôle sur les déterminations réalisées à partir de ces informations. Ces unités de réception sont par exemple portées l'une par le bateau maître V, les autres par des bouées ou des bateaux auxiliaires référencés par Q, B et T sur la figure.

Les unités de réception sur les bouées ou bateaux auxiliaires Q, B et T sont dites "passives" par opposition à celle montée sur le bateau maître r, qui est associée à des moyens d'émission.

A réception des signaux acoustiques, les unités portées par les bouées ou bateaux auxiliaires Q, B, T transmettent par voie hertzienne au bateau maître V les temps auxquels les signaux de réponse des différents transpondeurs P sont reçus.

Elles transmettent également au bateau maître V leurs données de positionnement de surface.

A cet effet, le bateau maître V, ainsi que les bouées ou bateaux auxiliaires Q, B et T présentent par

exemple des moyens de localisation GPS qui permettent de connaître leur position en temps réel.

La transmission entre les bouées ou bateaux auxiliaires Q, B, T et le bateau maître V se fait par exemple en mode TDMA.

Ces différentes informations (temps auxquels les réponses des différents transpondeurs P sont reçues par les unités de réception - coordonnées des bouées ou bateaux auxiliaires Q, B, T, ainsi que du bateau maître V) sont centralisées dans une unité de traitement qui calcule en temps réel, à partir de ces données, la position des transpondeurs P et donc celle du câble C au fur et à mesure qu'il se déroule avant de se mettre en place sur le sol marin.

On notera également que le câble C peut avantageusement comporter, à proximité immédiate des transpondeurs P, des capteurs de pression permettant de disposer en outre d'une estimation des profondeurs auxquelles se trouvent les transpondeurs P.

L'unité de traitement utilise cette information pour corroborer les positions calculées à partir des données transmises par les différentes unités de réception.

L'unité de traitement intègre un logiciel qui calcule en fonction de cette position les points d'impact théoriques du câble sur le fond marin, ainsi que les corrections à apporter à la trajectoire du navire pour optimiser la descente du câble C, de façon à minimiser l'écart entre la trace au sol prédite et la position optimale recherchée.

Comme on l'aura compris, le bateau maître V et les bouées ou bateaux auxiliaires Q, B et T et les moyens de détection GPS qu'ils portent constituent un réseau de surface très précis, par rapport auquel les transpondeurs sont positionnés.

Les techniques GPS utilisées mettent avantageusement en oeuvre des techniques de cinématique relative (KRGPS selon la terminologie utilisée par l'Homme du Métier), lesquelles techniques permettent de connaître avec une précision subdécimétrique la position relative de deux mobiles évoluant indépendamment à moins de 10 Km l'un de l'autre.

Bien entendu, d'autres systèmes de localisation satellitaire que le GPS pourraient être envisagés.

L'écartométrie entre les unités de réception est variable du fait du milieu marin. Avantageusement, le système comporte des moyens permettant de commander le déplacement des bouées et navires auxiliaires, de façon à modifier l'écartométrie et à optimiser le critère de "précision a priori" recherchée sur l'objet immergé ("PDOP" selon la terminologie anglo-saxonne).

L'interrogation des transpondeurs P par les moyens d'émission acoustiques que portent le bateau maître V est commandée par l'unité de traitement, par exemple toutes les deux secondes.

La liaison hertzienne entre le bateau maître V et les bouées ou navires auxiliaires B, T, Q est bidirectionnelle : simultanément à la commande de l'émission d'un signal d'interrogation par l'unité de traitement, ladite unité transmet aux différentes unités de réception - par voie hertzienne pour celles qui sont portées par les bouées ou navires auxiliaires B, T, Q, ou par une liaison interne pour l'unité de réception qui est portée par le bateau maître - un signal de synchronisation qui déclenche les compteurs destinés à permettre la mesure des temps auxquels les différents signaux de réponse des transpondeurs P sont reçus.

La synchronisation obtenue entre les unités de traitement et les unités de réception est d'une précision inférieure à 150 µs, ce qui induit un bruit de l'ordre

décimétrique sur une distance acoustique. Pour des mesures exigeant une précision ultime, ou réduit ce bruit d'un facteur 10 en combinant le signal logique de la TDMA au signal 1PPS issu du capteur GPS.

La résolution sur les temps auxquels les différents signaux de réponse des transpondeurs P sont reçus est inférieure à 250 ns.

La détermination des positions des transpondeurs P est faite en prenant en compte, pour chacun d'eux, les lignes de positions issues des temps de propagation mesurés à chaque point du réseau. Par exemple, l'unité de traitement met en oeuvre des tests de convergence (technique des moindres carrés sur plusieurs acquisitions).

Avantageusement également, les déterminations des positions acoustiques sont faites au moyen d'un traitement différentiel par rapport à un trajet acoustique aller-retour entre un point (fixe ou mobile) en surface et un point fixe au fond de l'eau, parfaitement topographié. Ceci permet, à chaque interrogation, de déduire la célérité instantanée du son - que l'on suppose localement (plus ou moins 1Km) et à court terme (plus ou moins 10 secondes) homogène - et sur le moyen terme de déduire le bruit lié aux variations de la célérité.

Les transpondeurs P sont par exemple chargés et codés lors du passage de la portion de câble qui les porte devant une porte magnétique en sortie du cabestan.

La position en temps réel du câble est par exemple restituée de façon graphique en trois dimensions sur un écran de sortie, de façon à permettre à un opérateur de visualiser en temps réel la descente du câble par rapport au fond marin et à l'emplacement théorique souhaité pour celui ci.

REVENDICATIONS

1. Système pour le suivi de la mise en place d'un câble sismique sur un fond marin à partir d'un bateau, comportant une pluralité d'émetteurs acoustiques qui sont répartis sur le câble et qui émettent chacun un signal acoustique identifiable, caractérisé en ce qu'il comporte un réseau flottant d'au moins trois unités de réception acoustique, des moyens pour connaître la position desdites unités de réception par rapport au bateau, ainsi que des moyens pour transmettre à une unité de traitement des temps correspondant à la réception par lesdites unités de réception, des signaux acoustiques émis par les émetteurs portés par le câble, l'unité de traitement comportant des moyens pour calculer, à partir de ces temps et des positions desdites unités de réception, la position desdits émetteurs et donc la trajectoire du câble au fur et à mesure que celui-ci est déroulé à partir du bateau.

2. Système selon la revendication 1, caractérisé en ce que les émetteurs acoustiques sont des transpondeurs qui émettent un signal acoustique à réception d'un signal acoustique d'interrogation et en ce que la position desdits transpondeurs est déterminée en fonction des temps entre l'émission des signaux d'interrogation et la réception à la surface de l'eau des signaux de réponse des transpondeurs.

3. Système selon l'une des revendications précédentes, caractérisé en ce que des moyens de transmission entre l'unité de traitement et les unités de réception comportent des moyens de communication hertzienne.

4. Système selon la revendication 2, caractérisé en ce que les moyens de transmission sont

bidirectionnels et en ce que simultanément à la commande de l'émission d'un signal d'interrogation par l'unité de traitement, ladite unité transmet aux différentes unités de réception un signal de synchronisation qui déclenche des compteurs destinés à permettre la mesure des temps auxquels les différents signaux de réponse des transpondeurs sont reçus

5. Système selon l'une des revendications précédentes, caractérisé en ce que des moyens pour connaître la position desdites unités de réception par rapport au bateau comportent des moyens de localisation radiosatellitaire.

6. Système selon la revendication 5, caractérisé en ce que lesdits moyens de localisation radiosatellitaire mettent en oeuvre une localisation GPS de type cinématique relative.

7. Système selon l'une des revendications précédentes, caractérisé en ce que les unités de réception sont au nombre de quatre ou cinq.

8. Système selon l'une des revendications précédentes, caractérisé en ce que le câble comporte en outre des capteurs de pression disposés à proximité des émetteurs acoustiques et permettant une estimation de la profondeur à laquelle lesdits émetteurs se trouvent.

9. Système selon l'une des revendications précédentes, caractérisé en ce que l'unité de traitement calcule en fonction de cette position une prédiction sur les points d'impact théoriques du câble sur le fond marin, ainsi que les corrections à apporter à la trajectoire du navire pour optimiser la descente du câble.

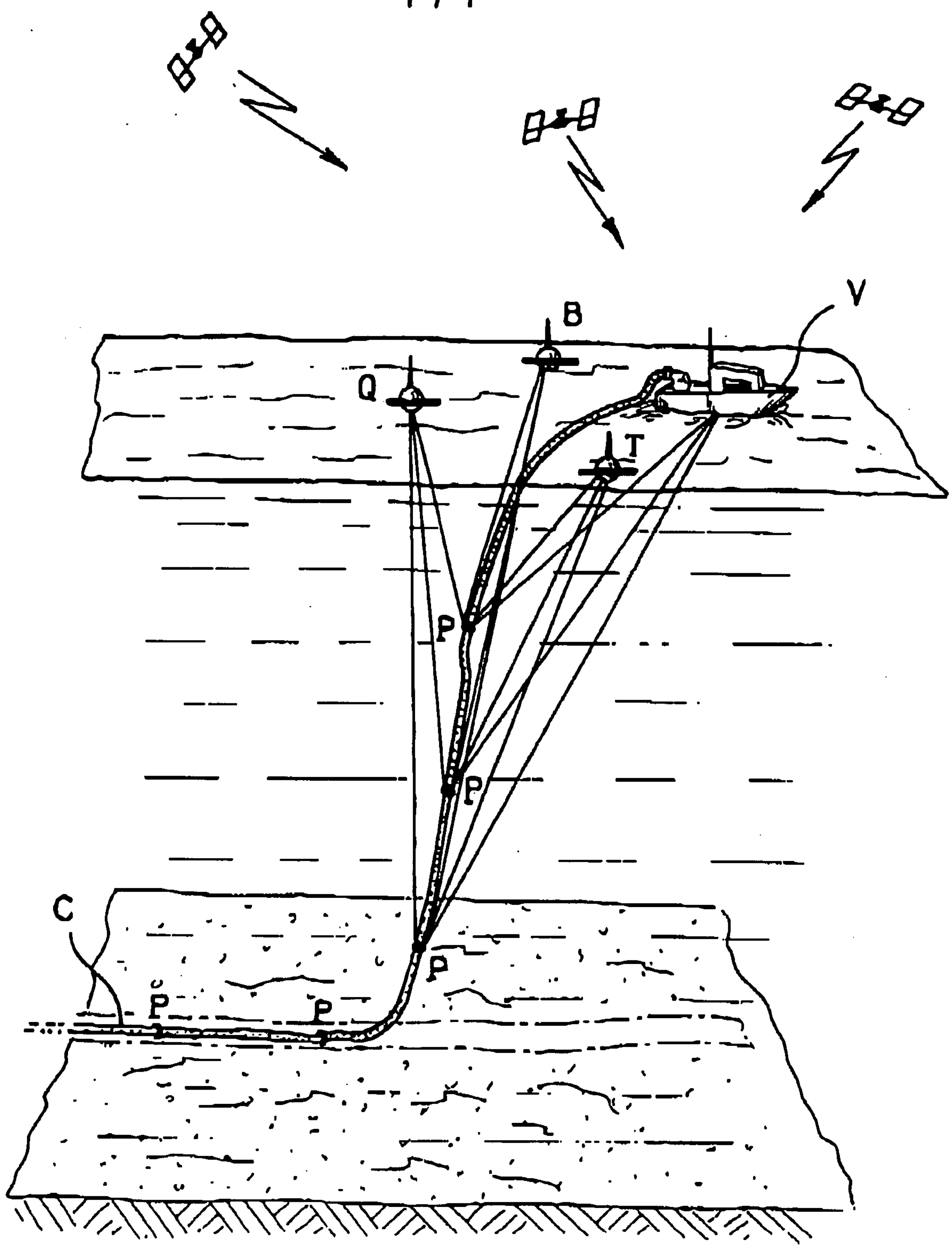

FIG_1

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FA 551643
FR 9716497

Catégorie	DOCUMENTS CONSIDERES COMME PERTINENTS Citation du document avec indication, en cas de besoin, des parties pertinentes	Revendications concernées de la demande examinée
Y	US 5 497 356 A (NORTON JR JOHN P ET AL) 5 mars 1996 * abrégé * * figure 2 * * colonne 1, ligne 38 - ligne 56 * * colonne 2, ligne 12 - ligne 14 * * colonne 2, ligne 28 - ligne 31 * * colonne 3, ligne 27 - ligne 54 * * revendications 1,2 * ---	1-6,8
Y	BELL B M ET AL: "NONLINEAR KALMAN FILTERING OF LONG-BASELINE, SHORT-BASELINE, GPS, AND DEPTH MEASUREMENTS" PROCEEDINGS OF THE ASILOMAR CONFERENCE ON SIGNALS, SYSTEMS AND COMPUTERS, PACIFIC GROVE, NOV. 4 - 6, 1991, vol. 1, no. CONF. 25, 4 novembre 1991, pages 131-136, XP000312715 CHEN R R * abrégé * * sections 1-4, 8 * ---	1-6,8
A	EP 0 308 222 A (HORIZON EXPLORATION LTD) 22 mars 1989 * abrégé * * revendications 1,2,6-8 * ---	1
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DOMAINES TECHNIQUES RECHERCHES (Int.CL.6)

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Date d'achèvement de la recherche	Examinateur
7 octobre 1998	de Heering, Ph.

CATEGORIE DES DOCUMENTS CITES

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T : théorie ou principe à la base de l'invention
E : document de brevet bénéficiant d'une date antérieure à la date de dépôt et qui n'a été publié qu'à cette date de dépôt ou qu'à une date postérieure
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PARIS

(11) N° de publication : **2 772 134**
(à n'utiliser que pour les commandes de reproduction)

(21) N° d'enregistrement national : **97 15484**

(51) Int Cl[6] : G 01 S 5/14, G 01 C 7/00, 13/00

(12) DEMANDE DE BREVET D'INVENTION A1

(22) Date de dépôt : 08.12.97.

(30) Priorité :

(43) Date de mise à la disposition du public de la demande : 11.06.99 Bulletin 99/23.

(56) Liste des documents cités dans le rapport de recherche préliminaire : *Se reporter à la fin du présent fascicule*

(60) Références à d'autres documents nationaux apparentés :

(71) Demandeur(s) : *AQASS Entreprise unipersonnelle a responsabilite limitee* — FR.

(72) Inventeur(s) : CHAUMET LAGRANGE MARC.

(73) Titulaire(s) :

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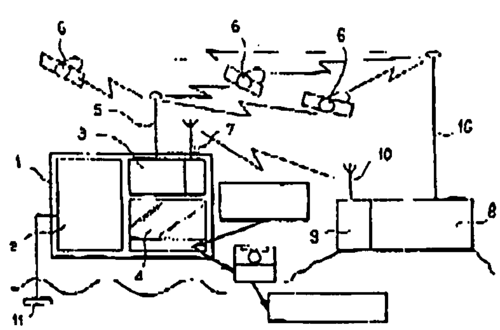
(54) DISPOSITIF POUR EFFECTUER DES LEVES HYDROGRAPHIQUES A PARTIR D'UNE EMBARCATION.

(57) Dispositif pour effectuer des levés hydrographiques à partir d'un embarcation comprenant un récepteur GPS différentiel (3) embarqué pour effectuer un positionnement par satellite, muni d'un moyen de communication HF ou UHF ou VHF, une station GPS différentielle (8) terrestre, munie d'un moyen de communication HF ou UHF ou VHF (9), un sondeur hydrographique (2) embarqué et sa base acoustique (11), un dispositif informatique embarqué (4) pour le traitement des données fournies par le sondeur et par le récepteur GPS différentiel.

Les appareils embarqués (3, 2, 4) sont choisis de petites dimensions et réunis dans un boîtier portable à l'intérieur duquel ils sont agencés de manière à y fonctionner sans modification de leur agencement, une ouverture prévue dans le boîtier permettant d'accéder à son intérieur pour extraire la base acoustique du sondeur hydrographique et faire fonctionner les appareils embarqués (3, 2, 4).



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La présente invention concerne un dispositif pour effectuer des levés hydrographiques à partir d'une embarcation.

Les levés hydrographiques sont nécessaires à l'établissement de cartes pour la navigation et la connaissance des fonds marins, fluviaux et lacustres ainsi qu'aux opérations de dragage.

Pour effectuer ces levés, on connait déjà des dispositifs comprenant :

- un récepteur GPS (Global Positioning System) différentiel embarqué pour effectuer un positionnement par satellite, muni d'un moyen de communication HF,
- une station GPS différentielle terrestre munie d'un moyen de communication HF,
- un sondeur hydrographique embarqué et sa base acoustique, et
- un dispositif informatique embarqué pour le traitement des données fournies par le sondeur hydrographique et par le récepteur GPS différentiel.

La station GPS différentielle terrestre calcule la correction de positionnement à appliquer au récepteur GPS différentiel embarqué et la lui transmet par les moyens de communication HF.

Les dispositifs actuellement disponibles pour effectuer ces opérations fournissent des résultats satisfaisants.

Néanmoins, dans les embarcations, ils constituent un équipement global encombrant et fragile de sorte qu'ils ne sont pas aptes à être déplacés fréquemment d'une embarcation à une autre.

De ce fait, pour faire face à d'éventuelles avaries affectant ces matériels, il faut disposer de plusieurs embarcations aptes à effectuer des levés, c'est-à-dire équipées chacune de son propre dispositif de levés hydrographiques.

De plus, lorsque les différents appareils constituant un dispositif de levés hydrographiques sont installés à demeure sur une petite embarcation, ils sont soumis aux intempéries, ce qui peut les endommager et leur entretien nécessite le déplacement d'un technicien spécialisé qui doit intervenir sur l'embarcation.

Enfin, il n'est pas économiquement raisonnable de multiplier les embarcations pour couvrir une vaste zone à surveiller ou pour stationner dans des lieux entre lesquels il n'existe pas de voie de communication nautique.

La présente invention vise à résoudre ces inconvénients.

La présente invention a pour objet un dispositif pour effectuer des levés hydrographiques à partir d'une embarcation, comprenant :

- un récepteur GPS différentiel embarqué, pour effectuer un positionnement par satellite, muni d'un moyen de communication HF ou UHF ou VHF,
- une station GPS différentielle terrestre, munie d'un moyen de communication HF ou UHF ou VHF,
- un sondeur hydrographique embarqué et sa base acoustique,
- un dispositif informatique embarqué pour le traitement des données fournies par le sondeur et par le récepteur GPS différentiel,

caractérisé par le fait que le récepteur GPS différentiel embarqué, le sondeur hydrographique embarqué et le dispositif informatique embarqué sont choisis de petites dimensions et sont réunis dans un boitier portable à l'intérieur duquel ils sont agencés de manière à pouvoir y fonctionner sans modification de leur agencement, une ouverture prévue dans le boitier permettant d'accéder à son intérieur pour extraire la base acoustique du sondeur hydrographique et faire fonctionner le récepteur GPS différentiel embarqué, le sondeur hydrographique embarqué et le dispositif informatique embarqué.

En d'autres termes, le dispositif selon l'invention réunit dans un même boitier portable tous les appareils qui sont traditionnellement installés à demeure sur l'embarcation, ce qui permet, d'une part de transporter facilement ces appareils d'une embarcation à une autre, et d'autre part de les mettre à l'abri des intempéries.

De plus, en cas de panne survenant dans l'un des appareils agencés dans le boitier portable, l'ensemble des quatre appareils peut être facilement remis à un technicien spécialisé qui peut effectuer la réparation sans avoir à se déplacer sur l'embarcation.

Dans un mode de réalisation particulier de l'invention, la station GPS différentielle terrestre est également portable, ce qui permet de constituer un ensemble intégralement portable, non seulement d'une embarcation à une autre, mais également d'un site à un autre.

Avantageusement, le dispositif informatique embarqué pour le traitement des données fournies par le sondeur hydrographique et le récepteur GPS différentiel est constitué par un ordinateur personnel

portable équipé d'un logiciel de contrôle des levés hydrographiques et d'un logiciel de gestion des levés et de contrôle de la navigation.

Le choix d'un ordinateur personnel portable permet d'assurer la simplicité de sa maintenance et éventuellement de son remplacement.

Pour le branchement d'une antenne GPS embarquée et d'une antenne HF ou VHF ou encore UHF embarquée, le boitier portable comporte, de préférence sur une plaque à bornes située dans ledit boitier, des prises démontables.

Cette plaque à bornes peut être postionnée par exemple dans un angle du boitier, accessible depuis l'extérieur par son ouverture.

Dans le but de mieux faire comprendre l'invention on va en décrire maintenant un mode de réalisation donné à titre d'exemple non limitatif, en référence au dessin annexé dans lequel :

- la figure 1 représente une vue d'ensemble schématique du dispositif selon l'invention,

- la figure 2 représente, en perspective, le boitier portable selon l'invention,

- la figure 3 représente le système de positionnement GPS différentiel.

Le dispositif représenté à la figure 1 comprend un boitier portable 1 à l'intérieur duquel sont agencés un sondeur hydrographique 2 tel que celui de la Société NAVITRONICS SYSTEM référencé NAVISOUND 100 A, un récepteur GPS différentiel embarqué 3 tel que celui référencé NR 108 de la Société DASSAULT SERCEL et un ordinateur portable 4 de type ordinateur personnel.

Ces trois appareils sont reliés entre eux de la manière suivante :

Le sondeur hydrographique 2 envoie à l'ordinateur portable 4 l'enregistrement numérique du fond qui est visualisable sur l'écran de l'ordinateur, ainsi que l'identification des sondes et leurs positions qui sont enregistrées sur le disque dur de l'ordinateur.

Une antenne GPS 5 est prévue sur le boitier portable 1 pour capter les signaux de plusieurs satellites géostationnaires 6.

Une autre antenne 7 HF ou UHF ou VHF est également prévue pour communiquer via un récepteur intégré ou récepteur GPS avec une station GPS différentielle terrestre 8 munie d'un émetteur HF ou UHF ou VHF 9 qui est aussi équipé d'une antenne 10 de ce type.

Le récepteur GPS différentiel 3, tenant compte des correctifs de positionnement fournis par la station GPS différentielle 8, détermine les coordonnées (X,Y) d'un point sondé de la manière qui sera décrite ci-après et ces coordonnées sont transmises à l'ordinateur portable 4.

Ce dernier exécute un logiciel de gestion des levés et de la navigation ainsi qu'un logiciel de saisie et de contrôle des levés à partir des positions calculées par le récepteur GPS différentiel 9 et des données de sondage fournies par le sondeur hydrographique.

Comme logiciels appropriés, on peut citer par exemple le logiciel HYDRONAV, commercialisé par la société NAVITRONIC, qui assure la gestion des levés et le contrôle de la navigation et le logiciel HYDROCONTROL de contrôle des levés, commercialisé par la Société PSI.

Le sondeur 2 est relié à une base acoustique 11 qui permet de mesurer la profondeur et peut fonctionner à 30 KHz pour les milieux vaseux ou à 200 KHz pour les fonds durs.

Le boitier portable 1 est mieux visible sur la figure 2 sur laquelle il apparait que ledit boitier portable est parallélépipédique et comporte une ouverture frontale 12 et une ouverture dorsale 13 permettant l'accès aux trois appareils, à la base acoustique 11 et aux deux antennes 5 et 7 qu'il contient.

Des prises (non visibles) sont prévues dans le boitier pour brancher les antennes 5 et 7 et la base acoustique 11.

Pour le transport, les deux antennes 5 et 7 et la base acoustique 11 sont rangées dans le boitier dont les ouvertures frontale et dorsale sont obturées. L'intérieur du boitier est muni à cet effet de moyens de fixation (non représentées) des deux antennes 5 et 7 et de la base acoustique 11, pour éviter que ces dernières ne bougent dans le boitier et endommagent certains appareils.

Le boitier 1 est en outre muni de poignées 15 pour son transport.

A titre d'exemple, on peut réaliser le boitier en un matériau composite alvéolé avec les dimensions suivantes : 50 cm en longueur, 40 cm en hauteur, 40 cm en profondeur.

De préférence, le boitier portable est conçu pour être étanche au moins aux ruissellements et comporte des moyens de ventilation (non représentés), ce qui lui permet de s'adapter à toutes sortes de conditions d'environnement.

Il est en outre monté sur des supports constitués par des amortisseurs (non représentés).

Sur la figure 3 on a représenté le récepteur GPS 3 et la station GPS 8 ainsi que l'ordinateur portable 4 pour illustrer la méthode de positionnement GPS différentielle.

Le récepteur GPS 3 détermine la position de l'embarcation. La station terrestre 8, qui comporte une antenne GPS 16, effectue la même opération.

On sait que le positionnement GPS ne fournit pas une précision suffisante.

Il existe donc une erreur de positionnement qu'il faut corriger pour connaitre les coordonnées exactes de l'embarcation.

Cette erreur est déterminée par comparaison de la position réelle connue (X_t réel, Y_t réel) de la station terrestre et de ses coordonnées calculées par triangulation (X_t,Y_t).

Une fois cette erreur (ΔX,ΔY) déterminée, elle est envoyée par l'émetteur 9 au récepteur HF du récepteur GPS 3 qui corrige en conséquence son calcul de positionnement pour retrouver les coordonnées exactes de l'embarcation.

Par cette méthode différentielle, on peut déterminer la position de l'embarcation avec une précision comprise entre 1 m et 5 m sur un rayon de 100 km.

Sur un rayon limité à 10 km, on peut atteindre une précision de 1 à 2 m, ce qui est particulièrement utile en zone portuaire à proximité des ouvrages.

Les coordonnées exactes de l'embarcation sont transmises à l'ordinateur qui représente sur son écran la route suivie par l'embarcation au cours du sondage et qui enregistre lesdites coordonnées sur son disque dur.

Il est bien entendu que le mode de réalisation qui vient d'être décrit ne présente aucun caractère limitatif et qu'il pourra recevoir toute modification désirable sans sortir pour cela du cadre de l'invention.

REVENDICATIONS

1. Dispositif pour effectuer des levés hydrographiques à partir d'un embarcation comprenant :

- un récepteur GPS différentiel (3) embarqué pour effectuer un positionnement par satellite, muni d'un moyen de communication HF ou UHF ou VHF.

- une station GPS différentielle (8) terrestre, munie d'un moyen de communication HF ou UHF ou VHF(9),

- un sondeur hydrographique (2) embarqué et sa base acoustique (11),

- un dispositif informatique embarqué (4) pour le traitement des données fournies par le sondeur et par le récepteur GPS différentiel, caractérisé par le fait que le récepteur GPS différentiel (3) embarqué, le sondeur hydrographique (2) embarqué et le dispositif informatique (4) embarqué sont choisis de petites dimensions et sont réunis dans un boitier portable à l'intérieur duquel ils sont agencés de manière à y fonctionner sans modification de leur agencement, une ouverture (12,13) prévue dans le boitier permettant d'accéder à son intérieur pour extraire la base acoustique du sondeur hydrographique et faire fonctionner le récepteur GPS différentiel (3) embarqué, le sondeur hydrographique (2) embarqué et le dispositif informatique (4) embarqué.

2. Dispositif selon la revendication 1, caractérisé par le fait que la station GPS différentielle (8) terrestre est également portable.

3. Dispositif selon l'une quelconque des revendications 1 et 2, caractérisé par le fait que le dispositif informatique (4) embarqué pour le traitement des données est constitué par un ordinateur personnel portable équipé d'un logiciel de saisie et contrôle des levés hydrographiques et d'un logiciel de gestion des levés et de la navigation.

4. Dispositif selon l'une quelconque des revendications précédentes, caractérisé par le fait que le boitier portable (4) comporte intérieurement et de préférence sur une plaque à bornes, des prises étanches (14) pour une antenne GPS (5) embarquée, pour une antenne HF ou UHF ou VHF (7) embarquée et pour la base acoustique (11).

5. Dispositif selon la revendication 4, caractérisé par le fait que l'intérieur du boitier portable (1) est muni de moyens de fixation des deux antennes (5,7) et de la base acoustique (11) pour le transport du boitier, l'ouverture (12,13) du boitier étant alors obturée.

6. Dispositif selon l'une quelconque des revendications précédentes, caractérisé par le fait que le boitier portable (1) est étanche au moins aux ruissellements.

7. Dispositif selon l'une quelconque des revendications précédentes, caractérisé par le fait que le boitier portable (1) est muni de supports constitués par des amortisseurs.

8. Dispositif selon l'une quelconque des revendications précédentes, caractérisé par le fait que le boitier portable (1) comporte des moyens de ventilation.

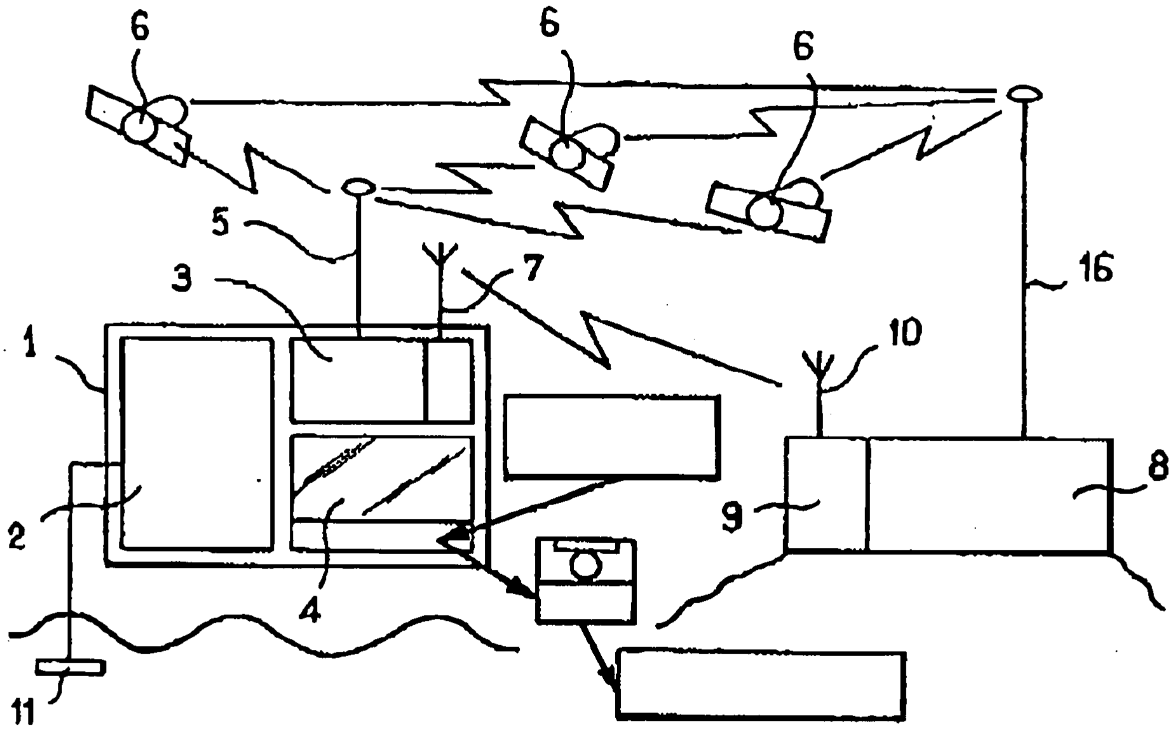

FIG.1

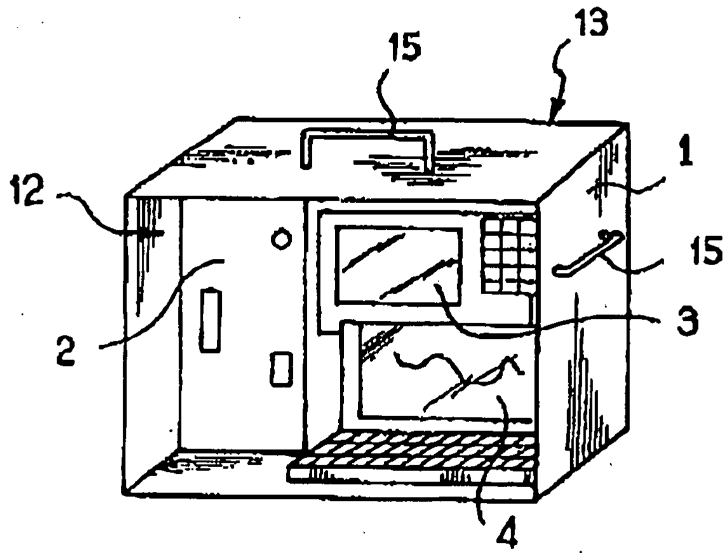

FIG.2

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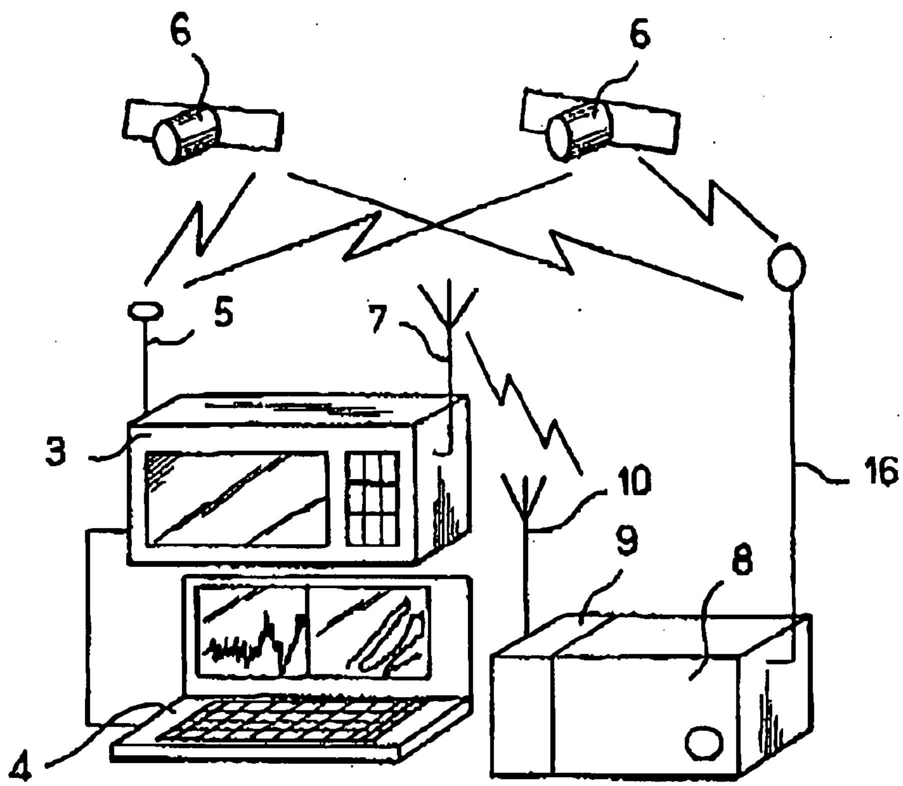

FIG.3

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DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie	Citation du document avec indication, en cas de besoin, des parties pertinentes	Revendications concernées de la demande examinée
X	WO 97 04334 A (LOWRANCE ELECTRONICS MFG ;WEBER RONALD G (US); RUEDY WILLIAM R (US) 6 février 1997 * abrégé * * page 1, ligne 8 - ligne 21 * * page 3, ligne 1 - ligne 35 * * page 5, ligne 26 - page 7, ligne 12 * * page 8, ligne 30 - page 9, ligne 2 * ---	1,3
A	PATENT ABSTRACTS OF JAPAN vol. 097, no. 006, 30 juin 1997 & JP 09 053936 A (UNYUSHO DAISAN KOWAN KENSETSU KYOKUCHO;FURUNO ELECTRIC CO LTD), 25 février 1997 * abrégé * ---	1
A	DE 296 18 253 U (TAUBE REINHARD DIPL ING ;MEINKE PETER PROF DR ING (DE); BLOEM EWOU) 15 mai 1997 * revendication 1 * ---	1
A	US 5 689 475 A (CHAUMET-LAGRANGE MARC) 18 novembre 1997 * colonne 5, ligne 42 - ligne 47 * * figure 3 * ---	1
A	US 5 559 754 A (CARNAGGIO FRANK S ET AL) 24 septembre 1996 -----	

DOMAINES TECHNIQUES RECHERCHES (Int.CL.6)

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1

Date d'achèvement de la recherche	Examinateur
1 septembre 1998	de Heering, Ph.

CATEGORIE DES DOCUMENTS CITES

X : particulièrement pertinent à lui seul
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To:	The Office of the Commissioner for Patents Attention: Magdalen Greenlief	**From:**	Liangang (Mark) Ye
Fax:	571-273-0125	**Fax:**	713-689-1977
Phone:		**Date:**	11/27/2007
Re:	Request for Participation in The Patent Prosecution Highway (PPH) Pilot Program Between the UKIPO and the USPTO	**Pages:**	Fax 1 of 3 – 52 pages ← ← ← Fax 2 of 3 – 44 pages Fax 3 of 3 – 51 pages

☑ **Urgent** ☑ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **Please Recycle**

● **Comments:**

In re Application of: James Edward Martin *et al.*	Group Art Unit: 3662
Application No.: 10/530,695	Confirmation Number: 7716
Filing Date: October 13, 2003	Examiner: Unknown
Title of Invention: Method and Apparatus for Positioning of Seismic Sensing Cables	Attorney Docket No.: 14.0223-PCT-US

Attached for your consideration is Form PTO/SB/20 – Request for Participation in The Patent Prosecution Highway (PPH) Pilot Program and Petitions to Make the Above-identified Application Special Under the PPH Pilot Program with attachments.

Respectfully submitted,

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